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ASTRONAUTICAL ACTIVITIES IN GERMANY

BY DIPL. ING. H. H. KOELLE*

1. The History of the Astronautical Movement in Germany

Real astronautical activities began, in Germany, with the publication of the famous book *Die Rakete zu den Planetenräumen* by Professor H. Oberth as early as 1923. This small book, which opened the scientific discussion on space-flight in Germany, was followed by Hohmann's *Die Erreichbarkeit der Himmelskörper*, the third edition of Oberth's book *Wege zur Raumschiffahrt* and other books by Valier, Gail and Ley, some of more popular nature. These books not only enlarged rapidly the number of space-flight enthusiasts but increased also the number of engineers and scientists interested in this problem. Thus the *Verein für Raumschiffahrt* was founded on July 5, 1927, in Breslau by J. Winkler and others. This was the first association for space-flight in the world. The journal *Die Rakete* was published from 1927 to 1929, but as the history of this society has been so well described by W. Ley,[21] no further details will be given here.

When the German government took over rocket development in 1933/34, not much activity was possible on a private basis. However, a small group of students associated with the observatory of the University of Breslau founded the old *Gesellschaft für Weltraumforschung e.V.* on August 18, 1937, on the initiative of H. K. Kaiser. This group headed the astronautical movement in Germany until the second world war ended. Its activities were limited due to military interest in rockets by the government, which disliked activity by private groups. However, it was possible to publish the journal *Weltraum* from 1939–43 with some interruptions caused by the difficulties in war time. The number of members rose to 400, but activities were stopped some time before the war ended.

On the other hand a large amount of money and work was spent in the field of rocketry by the German government. The history of the Peenemünde rocket centre has already been reported by W. Dornberger[22] and K. A. Ehricke[23] and requires no further details here. However, it should be mentioned that besides this place a great number of well-known firms were active in rocket research, development, or production; for example: Air-Force Research Centre for Rockets at Trauen; Rocket Test Station at Grossendorf; Schmidding;

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Prof. Dr. W. Schaub (right) presents the second "Hermann Oberth Medal" to Dr. E. Sänger (left) in Stuttgart, 1951.

(The first medal was awarded to M. Ananoff, and subsequent recipients include Mr. A. V. Cleaver of the B.I.S.)

The 1953/54 GfW Council

Left to right: A. Fritz, H. Hoeppner, Dr. H. G. L. Krause, Dipl. Ing. H. Gartmann, Prof. Dr. K. Schütte, Dr. E. Roessger, Reg. Dir. Dr. F. Gerlach and F. L. Neher.

Rheinmetall-Borsig; Ruhrstahl AG; WASAG; Mittelwerke; Walter Werke; Zeppelin Werke; Heylandt; Heinkel; Messerschmidt; Junkers; Dornier; Daimler-Benz; BMW and various other firms, research institutes and organizations.

Some tens of thousands of engineers, scientists and workers were thus connected with rocketry and a large number of those were either already interested in the astronautical movement or were infected by this work with the "virus of astronautics." By this impressive effort of the new-born rocket industry a solid base was formed for future activities in this field. The results of the German rocket development during the war and their influence on the future development are discussed in books by Ley,[21] Dornberger,[22] Stemmer[24] and many others.

2. The "Gesellschaft für Weltraumforschung e.V." Stuttgart

All German activities in the field of rocketry and astronautics collapsed with the end of the war, the material and scientists were spread all over the world, and very little left in Germany. Hardly three years after the war a few enthusiasts again raised their voices and looked for possible ways to start activities towards space-flight again. This was not easy, as Germany was split into four zones and occupied by countries with good reason to dislike any German rocket activities. Thus even the word "space-flight" could not be used before 1948 and was still disliked afterwards. Therefore the name "Gesellschaft für Weltraumforschung" (Society for Space Research) was chosen again. The legal foundation of this new society was prepared by the author (at that time a student at the Technical University at Stuttgart) and took place on January 28, 1948. Fifty-one members—most of them students—joined the new society the same day. The society was incorporated on August 5, 1948. (The individual Councils of the society since this year are given in Appendix I.) A Consulting Committee was formed in 1949 to assist the Council, the first director of this committee being Professor Dr. H. Siedentopf, a well-known German astronomer. As early as 1949 the first working committees had been formed, trying to organize limited team work on selected problems. The progress of the work undertaken by the technical and scientific groups was not very encouraging as the number of good engineers and scientists available was small. Furthermore, most of these had their own problems to solve and were not in a position to perform unpaid work on a larger scale. It was found out—as probably by all other astronautical societies—that such working teams are effective only if individuals are available to be the "motors" of such groups. This was the case also in the GfW and thus the working groups were and are active only for a limited time so long as someone pushes the others. A detailed report on the working groups and their activities is beyond the scope of this paper.

A great part of the efforts of the GfW Council was directed towards international co-operation in astronautics. Communications were exchanged with the existing astronautical societies and groups, especially with the B.I.S. The members of the GfW agreed to a resolution prepared by H. Gartmann suggesting an intensive international co-operation and the preparation of an International

The participants of the 3rd International Congress were welcomed to Stuttgart by a display of the flags of their countries opposite the Hauptbahnhof (main station) in September, 1952.

The German Federal Minister of Transportation (left) and the author (right) entering the rocket and space-flight exhibition held at the Landesgewerbemuseum during the 3rd International Congress in Stuttgart, 1952.

Astronautical Congress. This resolution was sent to all known astronautical societies in June, 1949. The idea was accepted abroad and led to the First International Astronautical Congress at Paris in September, 1950, prepared by A. Ananoff. The GfW was represented at this important congress by Dr. G. Loeser and H. H. Koelle.[5]

An archive, a slide collection and a picture service were founded during 1949/50 in order to assist local activities. The annual meeting decided in January, 1950, on the yearly presentation of the "Hermann-Oberth-Medal" which was to be awarded to distinguished persons for merits in the field of astronautics. A "Roll of Honour of Astronautics" was presented to the GfW by Professor Dr. E. Heinkel also in January, 1950. Individual members concentrated their attention, around this time, on proposed classifications for astronautics. The best known is the proposal of Dr. E. Sänger, published recently.[25] Also in 1950 the research series of GfW publications was started.

The first local sections of the GfW were formed in Hamburg, Stuttgart, Frankfurt and Nürnberg during 1950. Sections in München, Düsseldorf, Hanover and Berlin were founded in the following year. The chairmen of the individual sections formed an administrative consulting committee, assisting the Council in such questions. Professor Dr. E. Heinkel founded another prize (Ernst-Heinkel Prize) in order to support scientific work in the field of astronautics. This prize is awarded in a certain period of time for the best research report published in the research series of the GfW. Some important corporate members entered the GfW this year, such as the Ministry of Traffic, the Ministry of Economics and the Ministry of Communication of the German Federal Republic, and well-known firms such as Daimler-Benz AG and others.

The year 1952 was very successful, it was something like a peak in the GfW activities. The Third International Astronautical Congress was prepared and held at Stuttgart from 1st to 8th September.[9] This congress was opened by the German Minister of Transportation, Dr. H. C. Seebohm, personally. This was the first time that a member of the government in such a high position had shown such official interest in the international astronautical movement. It seems to be also of greatest importance to us that Dr. Seebohm personally is a member of the GfW. A rocket and space-flight exhibition—probably the largest ever held in the world—was shown during this Congress for the first time and was visited by more than 16,000 people.

Another scientific meeting connected with an exhibition took place during 1953 at Düsseldorf, which is the centre of the industrial district between the Rhine and Ruhr rivers. Many new members and good publicity were the results of this meeting. The GfW was represented by large delegations at all international astronautical congresses. The average number of German delegates was thirty, and about six to eight papers were contributed by them. The chief delegates for the London Congress were Dr. G. Loeser and H. H. Koelle, and for the following congresses Professor Dr. K. Schütte and Dr. F. Gerlach. The first President of the IAF, Dr. E. Sänger, and the first Vice-President, Dr. G. Loeser, were also members of the GfW.

Two daughter societies were founded with the support of the GfW in 1952 and 1954 respectively, i.e. the Deutsches Raketen- und Raumfahrt Museum

and the Forschungsinstitut für Physik der Strahlantriebe, which will be mentioned later.

The present activities of the GfW are modest, as the administrative work absorbs nearly all the capacities of the Council and not enough money is available to pay a clerk. The problem to develop great activity with little money has not yet been solved.

3. The "Deutsches Raketen- und Raumfahrtmuseum e.V."

As mentioned above, an exhibition was shown during the Third International Astronautical Congress at Stuttgart in September, 1952. This exhibition was prepared by the Gesellschaft für Weltraumforschung e.V. under the direction of the members A. Fritz, H. Hoeppner and Th. Laessig. It was felt after the Congress that this exhibition should be a permanent institution, and for legal and administrative reasons, as an independent body not associated with the GfW but co-operating with it. Thus the legal foundation of the Deutsches Raketen- und Raumfahrtmuseum e.V. (German Museum for Rocketry and Space-Flight) took place on November 1, 1952.

The following council was elected: A. Fritz (Chairman); M. Benndorf (Deputy Chairman); H. Hoeppner (Technical Director); Dr. F. Gerlach (Chairman of the Curatorium).

The following aims are included in the laws of the museum, which has the legal form of an incorporated society:

(*a*) To collect historical and present technical and literary material on astronautical development and to make it available to the public.

(*b*) To prepare an exhibition for educational purposes and lecturing, and to demonstrate the present stage of development in the field of rocketry and astronautics.

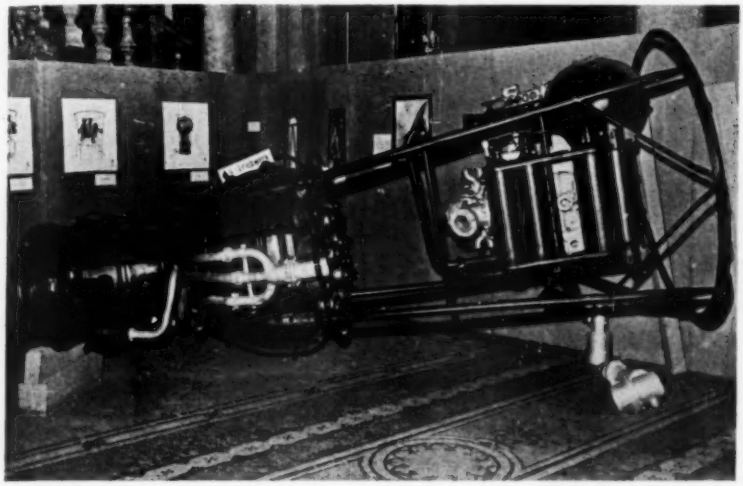
All interested people of all nations are invited to co-operate. The present number of members is about thirty-five. Three bulletins and one annual report contain details on the activities of the museum. Only the most important data will be given in this survey report:—

1. Exhibitions:

Town	Date	Square metres	Number of visitors
Stuttgart	Sept. 1–28, 1952	1,000	16,000
Karlsruhe	Nov. 9–23, 1952	1,600	10,000
Braunschweig	Feb. 28–Mar. 8, 1953	400	30,000
Kopenhagen	Apr. 16–25, 1953	300	90,000
Balingen	May 1–10, 1953	400	120,000
Düsseldorf	May 16–24, 1953	3,000	15,000
München	June 20–Oct. 11, 1953	500	3,000,000

Two small exhibitions were shown in Nürnberg and Reutlingen with 200 and 100 sq. m. and 50,000 and 8,000 visitors respectively by other organizers with the material of the museum.

The exhibition in München was a part of the German Traffic exhibition and explains the large number of visitors. The money spent for preparing the



An original A4 rocket motor on display at the German Rocket and Space-Flight Museum.

exhibition and buying the material amounted to about DM.70,000. It is regretted that a room is not yet available for a permanent exhibition, but it is hoped that such a room will be available in about two years in Stuttgart. The permanent office of the museum is: Reinsburgstr. 54, Stuttgart, Germany.

The council of the museum hopes to be in the position to enlarge the material of the museum, to prepare a permanent exhibition and to make this museum the nucleus of an International Astronautical Museum to be founded some time in the future. At present this museum has the largest known collection of astronautical material in the world.

4. The "Forschungsinstitut für Physik der Strahlantriebe e.V."

Even in the Constitution of the GfW in 1948 is found the statement that the GfW has the goal of preparing and supporting the foundation of a German Astronautical Research Institute. However, it was four years until the time was ripe to undertake steps in this direction. The actual preparations towards a research institute in the field of rocketry were started by the author in March, 1952, and were carried on by the Council of the GfW. It was a difficult and long journey to obtain the support of the local and federal government as well as the active assistance of the industry. Fortunately the plans of the GfW were in agreement with similar plans of the Technische Hochschule, Stuttgart (Technical University, Stuttgart) which planned an Institute and Chair for Combustion- and Rocket Research. As the funds of the Government for this purpose were not expected to be available before 1956, a provisional solution was strived at. The plans of the GfW and the Technische Hochschule were co-ordinated and found the support of all interested organizations and persons.

The Chairman of the Curatorium of the "Research Institute for Physics—Jet Propulsion," Dr. Eckert and his deputy Min. Rat. Dr. A. Seifriz, Stuttgart, July, 1954.

The building in which the "Research Institute for Physics and Jet Propulsion"—headed by Dr. E. Sänger—is located, at Stuttgart airport.

The legal foundation of the new institute took place on July 8, 1954, at the airport of Stuttgart. The ordinary budget for the first year amounts to DM.140,000. Additional income is expected from research contracts. Well-known firms such as Daimler-Benz A.G., Robert Bosch GmbH, Ernst Heinkel A.G., Mahle KG. and others are the founding members.

The laws of the Institute indicate its purpose as follows:—The Institute will undertake fundamental and applied research in the transition range between aeronautics and astronautics. Individual fields are, among others—theory of jet engines (excluding turbo-jet engines) and rockets; physics of combustion; gas-radiation; physics of wall effects.

The following Curatorium for the Institute was elected by the founding members:—

(*a*) Dr. Eckert, Chairman (Daimler-Benz A.G.).

(*b*) Min. Rat. Dr. A. Seifriz (Deputy) (Wirtschaftsministerium, Ministry of Economics of Baden-Württemberg).

(*c*) Five other representatives of the industry, universities and the Government.

Dr.-Ing. E. Sänger and Dr. I. Sänger-Bredt were appointed scientific director of the Institute and F. Walter executive secretary. The present staff of the Institute consists of eight scientists and eight assistants, who started the work on August 1, 1954. At present the Institute is located at the airport of Stuttgart, about 7 miles south of the centre of the town.[13,19]

5. Other Astronautical Groups in Germany

An astronautical working group at the Archenhold-Stern-Warte, East Berlin, was the first active astronautical group in Germany after the war. It was founded in 1946. The activities of this group, having about thirty members headed by E. Maedlow, was limited to lectures and discussions on astronautical problems. This group was mentioned in the bulletin of the observatory until 1951 but it is very likely that it does not exist any more.

Several persons strived to refound the old Gesellschaft für Weltraumforschung as early as 1947. These endeavours led to the foundation of the Gesellschaft für Weltraumforschung e.V., Stuttgart, as reported already, and due to the geographical restrictions by the various occupation zones, to the foundation of the Südwestdeutsche Gesellschaft für Weltraumforschung e.V. at Frankfurt (Chairman, Dr. J. W. Goethe) in March, 1948, and of the Nordwestdeutsche Gesellschaft für Weltraumforschung e.V. at Stade (Chairman, H. K. Kaiser) in June, 1949. The Southwestern GfW at Frankfurt had a maximum membership of about twenty and never became an active society. It was finally dissolved in 1952 after some years of inactivity. The Northwestern GfW was luckier. It published a bulletin from 1949 to 1952, sometimes a little irregularly. A series of research papers was published also. This society developed local activities at Bremen, Hanover, Hildesheim and Braunschweig. Its nominal membership rose finally to nearly 150. It became a non-voting member of the IAF in 1951, but finally a decision was made by the members to dissolve it on behalf of the larger Gesellschaft für

Weltraumforschung e.V., Stuttgart. This amalgamation became effective at September 30, 1952, and at that time about thirty of its members became members of the GfW, Stuttgart.

A working group for space research was founded in Leipzig (Eastern Zone) by H. Ruppe and N. Litterst on August 2, 1948. This group was combined with the Ganswindt-Research Society, Lucka (founded shortly before), on April 26, 1949. The combined society was called Vereinigte Astronautische Arbeitsgemeinschaften (Combined Astronautical Working Groups) with headquarters in Leipzig. This new group published a mimeographed journal called *Ad Astra* beginning in May, 1949. The journal was edited by R. Köhler and N. Litterst. The last number published was No. 10 of December, 1950. This society was co-operating closely with the Gesellschaft für Weltraumforschung e.V., Stuttgart, and with the British Interplanetary Society. But this activity on an international basis made this society and its officers undesirable for the Government and the occupation forces. Some of the officers were even forced to leave the Russian Zone and went to Berlin. All activities of the society were completely stopped early 1951.

Another German society was founded in 1952 by A. Puellenberg at Bremen called Deutsche Gesellschaft für Raketenforschung (German Society for Rocket Research). This society developed some experimental activities with small powder rockets during the first months of its existence. Only one copy of a journal called *Raketenflugpost* was published. All activities of this society were discontinued in the following year due to personal difficulties within the society, which is no longer in existence.

6. Future Development in Germany in the Field of Rocketry and Astronautics

The future development will be determined to a large extent by the three astronautical organizations:

(*a*) Gesellschaft für Weltraumforschung e.V., Stuttgart (GfW).

(*b*) Forschungsinstitut für Physik der Strahlantriebe e.V., STGT (FPS).

(*c*) Deutsches Raketen- und Raumfahrtmuseum e.V., Stuttgart (DRRM).

The GfW will be also in the future a private society consisting of scientists and laymen interested in this field and especially in the idea of astronautics. The society may perhaps even change its name from "Society of Space Research" to "Society of Space-Flight Research," which it really is. The society will continue to provide its members with the latest information on the developments in astronautics by its journal *Weltraumfahrt*. The GfW will continue to support the International Astronautical Federation (IAF) and its scientific journal *Astronautica Acta*. Large scientific and technical contributions cannot be expected from the GfW due to limited funds and time available. Experimental work is also not to be expected. Individual scientists, being members of the GfW working on scientific and technical problems in their spare time, will publish their results in the known journals.

The FPS will carry out independent fundamental research and research contracts for the industry in Germany and abroad, and the German Government,

concentrating on ram-jet engines, rocket motors and atomic propulsion devices. The institute is expected to take up experimental work in the next year. Combustion problems will play an important róle in this programme of fundamental and applied research in astronautics. However, the institute does not intend to develop complete rockets, this task is left to industry. The FPS will play only a consulting róle in such plans. It is expected that the personnel of the FPS is increased to about twenty or even thirty, depending on the number of research contracts taken over and the regular budget.

The DRRM will continue with its efforts to collect material related to the problems of rocket development and astronautics. It is hoped that a nearly complete V2 can be obtained back from the U.S.A. for exhibition purposes. Rooms for a permanent exhibition may become available in about two years. Exhibitions at various places will be prepared in the meantime; some historical research is being started.

Some limited contributions to the development of small rockets and rocket motors may be delivered by aeronautical research organizations in connection with aeronautical developments. It is expected that some industrial groups will show interest in the production of rocket assisted take-off units or even in getting licences for the production of small anti-aircraft rockets. According to the latest information, the development and production of small anti-aircraft rockets (diameter up to one foot, and a payload up to 50 lb.) will be permitted in Germany according to the agreements obtained in Paris recently. Thus the way is open for experiments with rocket engines, but with limited performance. This limitation in size and performance is not considered as serious, as there will probably never be such large funds available permitting the development of large rockets. However, even this modest activity in rocket design, development, and production is expected to increase the number of scientists and engineers connected with rocket problems, thus supporting at the same time the idea of space-flight. It is hoped that these scientists and engineers will contribute to the development of astronautics, even as only a spare time job.

Another contribution to the development of rockets and astronautics will come from the universities. It is hoped and expected that the German technical universities will take up courses on rocket design and fields related to astronautics. A first lecture on the fundamentals of ram-jet and rocket motors was offered to the students by the Technische Hochschule Stuttgart in November, 1954. The lecture is to be given by Dr. E. Sänger. The participation of approximately seventy students proves the great interest of the academic youth in these problems. A chair for combustion and rocket research will be founded within the next two years. It is expected that other German universities will follow this example in due course.

Thus it is hoped that Germany will be able to contribute a modest part to the development of rockets and of the astronautical science, not forgetting that it is not our goal to develop rocket weapons but rocket vehicles enabling human beings to leave our own planet and achieve space-flight for the benefit of the human race.

(*Note.—This paper gives only the opinions of the author and does not necessarily represent the views of any private or government organization.*)

APPENDIX I

Councils and Consulting Committees of the GfW Council

1948: J. Gerhards (Chairman); H. H. Koelle.

1949: Prof. H. Oberth (Honorary President); H. H. Koelle (Chairman); H. Gartmann; V. Gradecak.

1950 (Jan.–June): Prof. H. Oberth (Honorary President); Prof. Dr. W. Schaub (Chairman); H. Gartmann; H. H. Koelle.

June 1950–51: Prof. H. Oberth (Honorary President); Prof. Dr. W. Schaub (Chairman); Dr. G. Loeser; Dr. K. Bunde; H. H. Koelle; H. Gartmann.

(Dr. K. Bunde and H. Gartmann were replaced during 1951 by Dr. W. Lohmann and H. Kühme.)

1952: Prof. H. Oberth (Honorary President); Prof. Dr. W. Schaub (Chairman until June, 1952); ORR. Dr. F. Gerlach; H. Kühme; H. H. Koelle; Prof. Dr. K. Schütte (Chairman from July on); Dr. E. Walker; H. Hoeppner; F. L. Neher.

1953–54: Prof. H. Oberth (Honorary President); Prof. Dr. K. Schütte (Chairman); Reg. Dir. Dr. F. Gerlach; H. Gartmann; A. Fritz; Dr. E. Roessger; Dr. H. G. L. Krause; H. Hoeppner; F. L. Neher; H. H. Koelle (extraordinary member).

Consulting Committee

1950–52:

Min. Dir. Dipl. Ing. L. Brandt.
Prof. P. Goerke.
Prof. Dr. G. Hase.
Dr. Dr. E. Langer.
Dr.-Ing. R. Merten.
Prof. Dr. Dr. Schmeidler.
Prof. Dr. H. Siedentopf.
Prof. Dr. A. Wewerka.
Dr. W. Brügel.
Prof. Dr. G. Hamel.
Dipl. Ing. H. Kuehme.
Dr. W. Lohmann.
Dr. jur. F. Rosenthal.
Dr. med. J. Schneider.
Prof. Dr. W. H. Westphal.

1952–54:

Staatssekretär Prof. L. Brandt.
Dr. U. T. Boedewadt.
Dr. W. Dornberger.
Prof. P. Goerke.
Prof. Dr. Dr. E. Heinkel.
Dr. F. J. Lauer.
Dr. W. Lohmann.
Dr.-Ing. E. Sänger.
Dr. med. J. Schneider.
Dr. E. Roessger.
Prof. Dr. A. Wewerka.
Dr. W. Brügel.
Prof. Dr. W. v. Braun.
Ing. R. Engel.
Prof. Dr. G. Hase.
Dr. H. G. L. Krause.
Dr. G. Loeser.
Dr.-Ing. R. Merten.
Prof. Dr. W. Schaub.
Dr. jur. F. Rosenthal.
Prof. C. J. Peirce.
Dipl. Ing. H. v. Zborowski.

APPENDIX 2

SOME DATA OF THE DEVELOPMENT OF THE GfW

	1948	1949	1950	1951	1952	1953	1954
Number of members ..	131	245	363	437	590	751	ca. 800
Increase of members ..	131	114	118	64	153	161	ca. 50
Increase of members in per cent.	—	87	48	20	35	27	ca. 7
Number of lectures ..	17	27	87	104	99	68	ca. 50
Total audience ..	830	812	7,025	10,040	7,323	ca. 5,000	ca. 3,000
Income (DM.) ..	1,727	1,684	3,926	7,578	38,648	13,826	ca. 14,000

RECENT RESEARCH ON THE MOON—2. BUBBLES AND STREAKS

BY H. PERCY WILKINS, Ph.D., F.R.A.S.

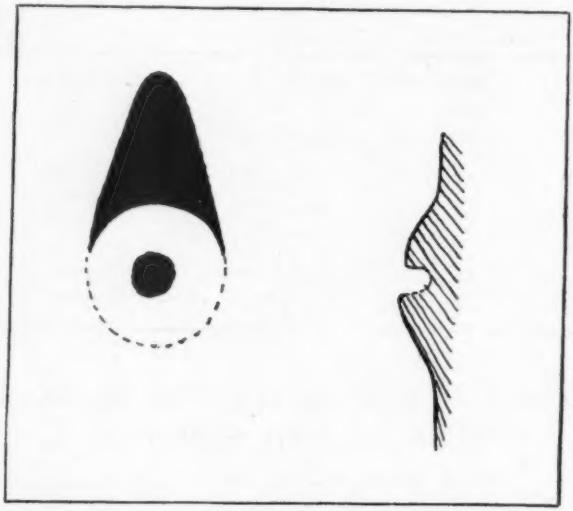
SUMMARY

This article deals with the strange domes or rounded structures of which many are now known, and also with the streaks or dusky markings considered by some observers to be due to the existence of some low form of lunar life.

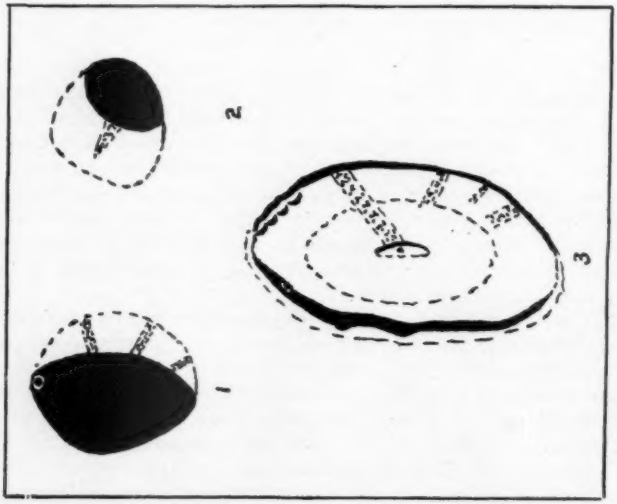
The Domes

The famous book[1] on the Moon by Nasmyth and Carpenter in which they presented the explosive, volcanic theory of the origin of the lunar craters, appeared in 1876. Nasmyth, who was the principal author, had made for himself a 20-in. reflecting telescope of the Cassegrain–Newtonian type, with speculum metal mirrors. With the aid of this instrument original drawings were made from which plastic models were prepared. Many of the striking illustrations in the book are photographs of these models and have always been regarded as most realistic representations of the lunar surface, although of necessity they break down in details.

Nasmyth's instrument was certainly adequate to reveal the more minute features, hence it is strange to read such remarks on the theory that the craters might be exploded bubbles, that some such bubbles or domes should have remained but none have been detected. He does indeed mention the one to the east of the Straight Wall, describing it as a low domed-formed hill, but does not mention any others. A moderate size instrument will show a considerable number of such domes or rounded hills, and the writer and Patrick Moore have listed about 100. A cluster of these objects will be found to the north-east of Copernicus, Linné is another, there are two near Arago, another in the Mare Crisium to the west of Picard, while the largest yet found occupies a good portion of the northern part of Darwin, a large crater-like object near the east limb. The dome within Darwin is crossed by a cleft. Observations in



Linné. 33 m. Refractor and section.



Streaks: 1, Conon; 2, Pickering; 3, Aristarchus.
1 and 3. 33 in. Refractor.
2. 60 in. Reflector.

early February, 1955 suggest that this cleft has now become a ridge since it held no internal shadow but was accompanied by a line of shadow of the eastern side. This surprising metamorphosis is being closely studied.

The majority have a diameter of between 2 and 3 miles and a height of a few hundred feet. They certainly resemble unburst bubbles, but the strangest thing about them is that nearly all have a deep pit right at the top. This position is almost universal, the pits being situated centrally and on the highest part, never at the side. Clearly the pit is fundamental to the feature and appears to imply an internal or volcanic origin and not a meteoritic. We can imagine meteors striking already existing domes or forming depressions, but it would be little short of miraculous that every meteor should have struck every dome exactly in the centre!

It has been stated that these domes appear dark under a low angle of illumination, probably due to the presence of numerous fissures, but this is not always the case, Linné, for example, being bright when it first emerges into the sunlight.

The remarkable thing is that, until recently, very few had been found, a fact which admits of only two explanations. Either they have been newly formed or the older observers were not as assiduous as commonly imagined. If newly formed we must admit that a certain amount of volcanic activity still lingers in the Moon, although it may be insufficient to form well-defined craters and only amounts to a slow welling out of magma to form a rounded hill, the vent being represented by the pit at the top.

Although the generally accepted view postulates that all volcanic activity on the Moon ended long ago, a famous student of our satellite, the late Professor W. H. Pickering, affirmed the contrary and believed in the existence of active vents, examples cited being the floor of Plato and in the hinterland of the Apennine Mountains.

It must be confessed that the existence of present lunar volcanic activity cannot be proved, as is usual in such matters an element of doubt remains. The earlier observers may have overlooked these strange objects, but if so, it is very remarkable that on the very sites where they declared depressions existed a dome now stands. After the dramatic announcement of Schmidt in 1866 of a change in Linné, a very shallow depression or crater was seen, while Espin, quoted by Webb,[2] declared that the spot to the west of Picard was a depression. To-day both are undoubted domes. It is possible, even probable, that local swellings of the surface take place here and there and that the resulting domes may not be entirely solid but cavernous in their interiors and, with a little tunnelling, would make excellent natural shelters for the space travellers of the future.

The Streaks

The older observers also seem to have overlooked almost in their entirety other features which are now easily seen and very common on the Moon, namely, the dusky streaks which can be seen on some crater floors and on the inner slopes of many crater walls. The first system of streaks to attract attention was that of Aristarchus, the brightest spot on the Moon. Dusky bands radiate from its brilliant central mountain and can be traced across the floor, up the inner slopes and "over the top." The little craters, Messier and Pickering so often observed on account of their extraordinary apparent

changes in shape, now both show a short, pointed streak on the floor but not yet on the slopes. This point was clearly seen with the Mount Wilson 60-in. reflector on June 17, 1954.

Even a 6-in. reflector will reveal streaks in many craters, but they are not shown on the maps and the drawings of the older observers. Did they exist in the times of Schroeter, Mädler or Schmidt?

If so, it is strange that they should have been overlooked. Even Goodacre only cites Aristarchus, and appears to have passed over what are now glaring features.

Little can be said as to the nature of the streaks. They may be due to some peculiarity in the surface, perhaps there has been faulting or the formation of narrow cracks. On the other hand there is nothing impossible in the idea that they are stains due to the presence of some low form of life, probably in the nature of lichens or fungus. If so, they may be regarded as lines or zones of vitality, and should many develop in close proximity to each other we would expect to find a dark patch or area. Now in the crater Eratosthenes there are such patches as well as individual streaks, moreover the patches seem to move about in an unpredictable manner. From this, Pickering deduced that they were probably caused by some kind of life because they *seemed able to choose their paths.*[3]

Needless to say, this idea has not been accepted by observers in general, but nobody can deny that the patches do move about very much in the way described by Pickering. Their nature and not their existence is questioned, and it is difficult to see how the enigma can be solved without actually visiting the Moon. Even the finest telescopes cannot bring the Moon sufficiently close to reveal objects less than 200 yards across.

We have evidence that two lunar features, the domes and the dusky streaks, are now more numerous than they used to be. Certainly the numbers known have greatly increased during the past twenty years. Although this is to some extent natural because they are being searched for, it does not explain why the earlier observers failed to detect them. It is even possible that we have evidence of streaks which have now vanished, for Mädler both described and drew four streaks running from north to south across the floor of Plato. It is certain that they do not now exist, such streaks as can be detected within this fine crater seem to range from east to west rather than from north to south. Professor Pickering declared the floor of Plato to be one of the most continuously active volcanic regions on the Moon. However this may be, it is clear that changes of some sort are and have been taking place on the lunar surface, and that in this respect our satellite is not the dead world it is so often assumed to be. The next article will deal with some curiosities of the surface and also with certain little-known facts regarding the larger craters.

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EXTRA-TERRESTRIAL OBSERVATORIES—THEIR PURPOSE AND LOCATION

By C. A. Cross, M.A.

(*A paper read to the N.W. Branch on November 20, and to the Midlands Branch on December 11, 1954.*)

SUMMARY

The progress of astronomy is greatly impeded by the Earth's atmosphere, its gravitation, and its rotation in space. Irregularities in the air prevent telescopic resolution of fine detail, light absorption in the air prevents measurements except in the narrow visible region, and luminosity of the upper air prevents long exposures by fogging photographic plates. The gravitational field causes deflections in the mechanical and optical structure of the telescope.

A telescope out in space suffers none of these disadvantages. It is shown that an 800-in. telescope in space would be capable of detecting solar systems like our own at distances of up to twenty light years. Their detection would indicate the likelihood of there being other intelligent life in the universe.

The construction of large parabolic mirrors in space is discussed, and it is suggested that they may be made from thin aluminized diaphragms of thermoplastic material.

Introduction

In order to appreciate the possibilities of an extra-terrestrial observatory we must first understand what are the current objectives in astronomy, and how they are being achieved. Perhaps the simplest way to obtain this overall picture is by examining the astronomical papers in *Science Abstracts*, Section A. In this way we find a total of 371 such papers in the year 1952, which are classified in Table I below.

TABLE I

Astronomical Papers in 1952

Subject	No. of papers	Percent. of total
Instruments and technique ..	13	3·5
Solar System	38	10·2
Sun	83	22·4
Stars	166	44·7
Time and geodetics	43	11·6
Radio astronomy	28	7·6
Totals	371	100·0

We shall see later why the Solar System comes so low in the list. The main effort clearly goes into the stars, and much of this is astrophysics. The Sun comes in for special attention as the most accessible star, and also because of its important effects on communications. Radio astronomy is the flourishing baby of the group.

Disadvantages of Observing from Earth's Surface

With this latter exception the method was usually to collect light from the object under study by means of a telescope, and to analyse this light by one or more specialized physical techniques. These included the use of the photographic plate to record both position and brightness, and the application of a

variety of methods of spectrometry and photometry. Direct observation of the light was hardly ever practised. The astronomer nowadays only uses his eyes in "guiding" the telescope so that it remains pointing in the correct direction throughout the experiment in hand.

All the telescopes at present in use are mounted on the surface of the Earth. There, all the light must come to them through the atmosphere, and the telescope must work in the Earth's gravitational field mounted on a foundation that rotates in space.

There is no doubt that the most important single factor restricting progress in astronomy is the Earth's atmosphere. There are three separate effects:

Firstly the inhomogeneities always present in the air cause minute irregular deflections of the light passing through it. These are visible to the naked eye as the twinkling of the stars. This effect of twinkling becomes more and more important as the aperture of the telescope is increased. Thus a six-inch telescope will often resolve fine detail down to the theoretical limit, but the larger apertures reach their limiting performance much less frequently. The one and two hundred-inch telescopes hardly ever achieve better resolution than would be obtained with thirty inches. They are built to collect light, and because of the imperfect atmosphere can never take full advantage of their theoretical resolving power. This is why our knowledge of surface detail on the planets has hardly progressed at all in the last fifty years. Work in this unrewarding field is left largely to enthusiastic amateurs, who spend long hours at the eyepiece waiting for the moments of good seeing which the eye can use though the photographic plate cannot.

Secondly, the atmosphere absorbs a part of the radiation passing through it. Although almost transparent to visible light, the air is opaque to both the shorter wavelengths (ultra-violet), and the longer (infra-red). The absorption does not therefore set a limit to the amount of visible light that can be collected by larger telescopes, so that as we have seen the major effort currently goes into spectrometry and photometry of fainter and fainter objects. Great advances would be possible even here if the measurements could be extended over a wider range of wavelengths.

Finally the night sky itself is faintly luminous. This light arises partly from the recombination of atoms and molecules that have been activated by sunlight, partly by bombardment of the air with atomic and larger particles from space, and partly from scattering of starlight in the air. This uniform feeble luminosity causes fogging of photographic plates that are given a prolonged exposure. It is this fogging that limits the faintest star so far detected to magnitude 22·5.

The effect of gravity and rotation can well be considered together. Because telescopes must be slowly turned in the gravitational field so as to maintain a fixed direction, the mechanical and optical structure is subject to varying loads. These structures suffer in consequence varying deflections. Great ingenuity has been expended in keeping these deflections within the very small tolerances required.[1] The difficulties increase in proportion with the cube of the size, and the two hundred-inch telescope may well be at the limit of practical achievement with present day materials of construction.

Observations outside the Atmosphere, Immediate Prospects

It is clear that a telescope in free fall out in space would suffer none of these disadvantages.[2] From such a position theoretical resolution would always be attainable for any size of mirror, there would be no absorption losses, and the sky light[3] would be reduced by a factor of three. (The remaining light is the zodiacal light, attributed to the scattering of sunlight by meteors in interplanetary space.) Moreover there would be no gravitational field to cause deflection of the structure, which would remain pointing in the desired direction indefinitely, without any complicated drives.

These advantages are, of course, only to be realized when the immense problems associated with placing and operating the equipment have been solved. At first we can only expect limited gains, and it is interesting to note that the first extra-terrestrial observatory has already been in operation,[4] i.e., in a spectrograph carried by an "Aerobee" rocket. Spectra of the sun were obtained extending from the ultra-violet to the soft X-rays. Thus for a few minutes we had an extra-terrestrial observatory operating in a close orbit around the Earth. Admittedly the orbit started and finished on the Earth's surface, but to extend its duration would only be a matter of bigger and better rockets. In principle the other techniques we need have already been tested and proved.

Thus in the immediate future we can expect the development of close satellites with small telescopes and telemetering and remote control systems, and with facilities for returning material data (photographic plates) to the Earth's surface. These may be followed by the more ambitious "probe" rockets, to the back of the Moon, and then out to Mars[5] and to Venus. In this way Man will at first explore the Solar System from an armchair. We may hope that this will prove to be only a transition period, paving the way for a personal exploration.

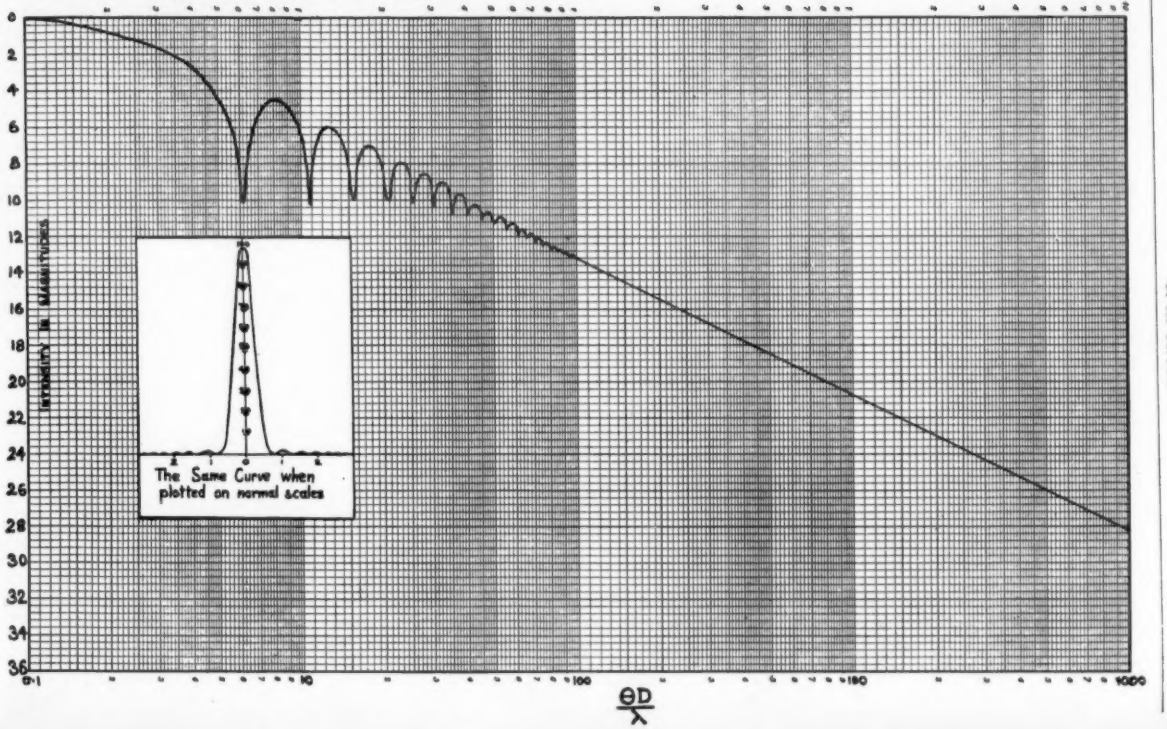
Future Possibilities

None of the equipment we have discussed so far will be large enough to improve materially our knowledge of the stars, and yet for the really important unsolved mysteries of astronomy we must look outside the Solar System. When Man has solved the technical difficulties of escape from the Earth, and starts upon his exploration of the Solar System, the opportunity will present itself of constructing very much larger telescopes in interplanetary space. These instruments will provide tremendous scope for development in the whole field of stellar astronomy, but in this paper I want to concentrate on a single question which shows how the removal of the restrictions that we have discussed opens up new and unorthodox possibilities.

Is there life in the rest of the universe?

It seems likely that interplanetary travel will not produce any satisfactory answer to this question, for the other planets of this system are not expected to support more than the lowest forms of plant life. If this is found to be so, then the best we can do will be to attempt to detect planets like our own circling the nearer stars. If there are such planets, then some of them would almost certainly be the abode of life.

FIGURE 1 – THE DIFFRACTION PATTERN FROM A CIRCULAR APERTURE, WHITE LIGHT.
(PLOTTED ON LOGARITHMIC SCALES)



A sphere of twenty light years radius encloses some 100 stars, and as this seems a worthwhile sample for a preliminary trial I have arbitrarily considered the problem of detecting our own Solar System at this distance. Table II shows the magnitudes and maximum separation from the Sun and the more important planets when viewed from this distance.

TABLE II

THE SOLAR SYSTEM AS SEEN FROM TWENTY LIGHT YEARS

Body:	Sun	Venus	Earth	Jupiter	Saturn	Uranus
Magnitude	3·9	27·26	27·96	25·2	27·87	30·95
Separation (seconds of arc)	—	0·117	0·163	0·845	1·56	3·13
Diameter of mirror to resolve (inches)	—	8,600	7,800	800	820	1,020

The detection of these feebly lit companions in the close vicinity of a moderately bright star is quite impossible for an earth-based instrument, and this point is firmly made in many text books. The impossibility lies, however, in the imperfections of the atmosphere rather than in the faults of optical instruments.

The theory of the resolution of unequally bright binary stars has been rigorously formulated,[6] and the theory shows reasonable agreement with experimental results,[7] except for the falling off in performance with large aperture caused by the atmosphere. Extension of this theory to the bodies of Table II represents a major extrapolation, which seems however to be quite firmly based.

The condition for resolution to be possible is that the central diffraction disc of the planet shall be at least as bright as the diffraction rings from the parent star which surround it. Normally this condition can be satisfied within the first few diffraction rings, but in this case we must calculate their brightness out to the 500th maximum. The Bessel functions needed for this purpose have only been tabulated up to $x = 15$, corresponding to some seven rings. For the outer rings we may use an approximation[8]:

$$J_1(x) = \frac{\cos\,(x - 2{\cdot}3562)}{(1{\cdot}5708x)^{\frac{1}{2}}} \quad .. \quad .. \quad .. \quad .. \quad (1)$$

Substituting these values in the normal equation for the ring intensity we obtain:

$$I \propto \left(\frac{J_1(x)}{x/2}\right)^2 \quad .. \quad (2) \qquad \text{and} \qquad x = \frac{\pi D \sin\theta}{\lambda} \quad .. \quad (3)$$

where I is the intensity, D the mirror diameter, λ the wavelength of light, and θ the angular deviation from the central spot.

If these intensity data are plotted as magnitudes, with the number of fringes on a logarithmic scale too, then the familiar picture of a bright central peak and faint diffraction rings (inset) assumes the form shown in Fig. 1.

By using Fig. 1 in conjunction with Table II we can immediately derive the diameter of mirror needed to resolve each planet. These diameters have been inserted in Table II. Knowing that the 200-in. telescope can detect 22nd

magnitude stars from the Earth's surface, it is clear that these mirrors would all have sufficient light grasp to record as well as resolve their respective planets. They would presumably be used in conjunction with an optical system such as Lyot developed in the coronagraph to eclipse artificially the light of the central star.

These considerations suggest that a 1,000-in. mirror of accurate figure mounted outside our atmosphere would be capable of detecting any "giant" planets circling stars up to twenty light years away. The existence of such bodies would be strong presumptive evidence for smaller planets, but these could not be detected directly.

Structure of Extra-terrestrial Observatories

I have shown elsewhere[9] how a large mirror used for delicate work on the stars could be protected from the Sun's radiation by siting it at an outer Lagrangian equilibrium point beyond Mars, where the Sun would be totally and permanently eclipsed by this planet. There remain the not inconsiderable problems of providing a mirror of this size in such an orbit, and of operating an observatory around it. I do not wish at this stage to go into a great deal of engineering detail, but it is clear from the most superficial study that even if all the space travel problems are solved we shall not be able to make the mirror on the Earth's surface and transport it to the orbit.

The construction of a tessellated mirror[10] at first sight appears promising, for the small unit mirrors could be readily transported and subsequently assembled out in space. Unfortunately the resolving power of a mirror built up from small units in this way is only that of the individual unit, although the assembly is an efficient light collector. Such systems would only be justifiable on the Earth's surface.

The only remaining alternative is to construct the mirror out in its orbit. The conventional methods of casting a disc then grinding, polishing and figuring it do not appear very practicable in these circumstances. I believe that if these large mirrors ever are made it will be by making use of a physical system which produces automatically the required optical surface. This sort of thing is well illustrated by the production of a paraboloid mirror by rotating a dish of mercury about a vertical axis. This arrangement has been successfully used to make mirrors 20 in. in diameter.[11]

Out in space a different piece of physics would be needed, and a very tentative recipe for the construction of a 1,000-in. mirror in free fall is as follows:

(1) Produce on Earth a disc of thermoplastic material, say 1/64 in. thick by 1,000 in. diameter. (Weight about 150 lb.)
(2) Roll up and transport into orbit.
(3) Unroll and stretch carefully on a circular frame.
(4) Turn the frame normally to the Sun's rays, and allow the diaphragm to soften. (Its melting point will have been suitably chosen.) At this stage the diaphragm will become an optical flat under the influence of the surface tension forces.
(5) Give the framework a small constant acceleration towards the Sun. The optical flat will deform into a paraboloid of rotation.
(6) Shade the surface from the Sun's rays. It will cool down and set.

(7) Stop the acceleration. So long as the diaphragm is not allowed to melt it will now retain the desired form.
(8) Aluminize in the usual way.

Such mirrors could be discarded and remade whenever the surface became damaged by meteors.

There are many points of absorbing interest in the consideration of the structure, control, and use of an observatory built around such a mirror, which cannot be dealt with in this paper. Nor can I deal with the similar field of speculation which opens with the development of radio astronomy out in space. In any case, radio astronomy has hardly yet found its feet on the ground. Perhaps in twenty years the radio astronomers will have a better idea of what extra-terrestrial equipment to ask for, and a better chance of getting it.

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"Let's look around a bit before we write our books, shall we?"
(Reproduced by courtesy of the Editor of "The New York Times Book Review").

THE LAW OF SPACE

By C. E. S. Horsford

SUMMARY

The conquest of Space and the operation of man-made vehicles in it will raise many new problems of a legal nature, both national and international. The writer seeks to examine some of these problems in the light of modern international law and suggests a possible method of solution.

Introduction

It is surely a strange thing that even before the international problems of this planet have approached a solution, the problems of another and entirely new medium present themselves to those who look ahead to the conquest of space. Yet here is a challenge which has effects far beyond the scientific and which involves more than the scientific in the vastness of its potentiality.

Once it is accepted that successful attempts have been or will be made beyond the frontiers of space, the lawyer and indeed the citizen will wish to know what rules shall be observed and what law shall prevail over the space-craft which will venture forth in ever-increasing numbers. It is to be apprehended that more than one nation may be involved, and thus a situation of potential antagonism is immediately created, and what sanctions shall there be to arrest it? Who shall own any territorial acquisitions on another planet or moon? How shall spaceships be controlled and piracy prevented? These are some of the questions which immediately spring to mind even upon a cursory glance at the subject.

Such questions can only, however, be answered or even tackled with reference to modern international law and custom based upon accepted legal principles, and it is to that field that the enquirer must turn his attention. The primary topic, upon which much has been written and much thought devoted, is that of air-space, the area above a nation's dominions.

The Law of Air-Space

It has long been recognized that a nation has sovereignty over the air-space above its territory and that other states have only such rights in it as are secured to them by convention.[1] In the Convention of Paris on Air Navigation in 1919, each party undertook to allow freedom of innocent passage in time of peace to aircraft belonging to the other parties. Certain conditions, however, were laid down which had to be observed. All aircraft had to carry certificates of airworthiness, certain prohibited zones might be established, routes and landing procedure might be prescribed and numerous other such regulations were accepted by the Convention as an integral part of the whole scheme. The Convention, however, did not succeed in establishing international air ways for regular airline services and that is still the case to-day, although the position has been greatly improved by the introduction and acceptance of the "Five air freedoms" as a result of the creation in 1944 of the International Civil Aviation Organization (I.C.A.O.) now recognized by the United Nations as a "Specialized Agency."

These "five freedoms" comprise the freedom to fly across foreign territory without landing—to land for non-traffic purposes, e.g. for refuelling—to put down freight and passengers originating in the state of the aircraft—to embark freight and passengers destined for that state, and, lastly, to embark or put down traffic destined for or coming from a third contracting state. International co-operation in the field of aviation has thus advanced considerably, but it must be remembered that all this legislation applies solely to civil aircraft in time of peace. Military aircraft are only allowed to fly over foreign territory by special permission.

So much for this brief incursion into the law of the air, but it will be seen at once that these regulations are not only inadequate but largely inapplicable to the new and vast medium into which our studies must be directed. Although John C. Cooper, the Director of the Institute of International Air Law, has proposed that "at any particular time, the territory of each state extends upwards into space as far as the then scientific progress of any state in the international community permits such state to control space above it," all operations in space will be conducted so far above what is now accepted as the air-space above a nation's territory, and so impossible will it be to observe any limitations of a territorial nature such as frontiers demand, that it is in the law of the sea that the answer would seem to lie.

The Law of the Sea

Here the long-established custom reigns that the high seas are free to every navigator whatever his colour or creed. This great juristic theory, upheld by the seamen of the first Elizabethan age and supported by the great international jurist, Hugo Grotius, has been universally accepted upon the international level, the exception arising in the case of territorial waters, over which jurisdiction is somewhat naturally claimed by every nation having a sea-board.

At the inception of international law, however, in the fifteenth century, the freedom of the high seas was by no means accepted by the great Powers of the day. Many nations claimed sovereignty over certain areas of the sea; for example, Venice claimed the Adriatic, England the North Sea, the Channels and certain areas of the Atlantic and Sweden and Denmark claimed the Baltic. Many such claims were disputed, but the principle of sovereignty was not; indeed, in 1493 the famous Papal Bull of Alexander VI presumed to divide the world into two halves between Spain and Portugal by an imaginary line drawn North to South-west of the Azores. This division proved wholly illusory and was openly flouted by the English seamen above all, who made a mockery of Spanish and Portuguese claims. One principle did emerge, however, which is of importance. It came to be accepted that some exercise of authority was necessary in order to constitute dominion both over sea or newly discovered land areas. The Roman legal principle of acquisition of territory by Occupatio-Discovery, came to mean that a successful title to what was known to lawyers as "terra nullius," or land belonging to no one, depended upon some definite evidence of the exercise of authority or colonization. But quite small actions might suffice, such as the planting of monuments and symbolic ceremonies, though it is doubtful whether any such acts would suffice to-day. Indeed, in

recent years, the requirements of a successful territorial claim in international law have become rather the exercise of practical government than the taking of physical possession.

A dispute arose in 1931 between Norway and Denmark in respect of Eastern Greenland over which Norway had proclaimed sovereignty. The matter was referred to the Permanent Court of International Justice at The Hague where Denmark was able to show numerous legislative and administrative Acts purporting to apply to the whole of Greenland. The Court said that a title by occupation involves two elements, "the intention or will to act as sovereign, and some actual exercise or display of authority."[2] The Court, taking into account the nature of the terrain and other matters, held in favour of Denmark on the grounds that a sufficient intention and exercise of authority had been disclosed.

Application to Space

How can all these various principles be applied to the question in hand and how far can analogies be drawn? It is reasonable to assume, firstly, that in the light of modern international theory, outer space itself is likely to be considered a free navigable area as are the high seas, subject only to certain sanctions and rules of control relating to the spacecraft themselves with which we will deal at a later stage. Secondly, however, comes the more complicated question of planetary discovery and exploration. Are such new worlds to be common in nationality, or able to be acquired by the first state to land on them and settle or control them?

New Worlds

The argument here is clearly twofold and there is much to be said on either side. The contender for freedom will maintain the difficulty of asserting governmental authority in these areas, since a brief visit by a spaceship could hardly be expected to satisfy the legal requirement of occupation. Oscar Schachter, the deputy director of the United Nations Legal Department, in an interesting article[3] on this subject suggests that scientific equipment might be left upon a planet which would serve not only as practical but also as symbolic evidence of possession. A powerful and cogent point in the argument for freedom is the obvious potential danger of wanton exploitation and rivalry between nations in the acquisition of new and vast territories in addition to the singular military advantages which such acquisition might afford to its owner.

However, the argument for state sovereignty can be supported upon the ground that while mere discovery without effective occupation or control does not create a title, international law does recognize what is known as an "inchoate title," that is, a temporary right to exclude other states until the discoverer has had a reasonable time to make an effective occupation. Such a title was considered by the arbitrator in the Island of Palmas award in 1928, where the United States claimed an island by virtue of discovery only, while Holland had for a considerable time exercised continuous and peaceful authority.[4] Such a title as discovery may confer must be converted into a true and definitive title by effective occupation within a reasonable time and

since this had not been done, the United States had forfeited any rights she may have originally had over the island. Again, the argument in favour of state sovereignty rests upon the desirability of creating an incentive to explore and develop any natural and mineral resources that may be discovered upon the planet concerned, since nations are not likely to be particularly altruistic in that regard, especially when great cost is sure to be involved.

International Law in Space

It is submitted that the answer to these problems lies in some form of international control. The political consequences of any substantial conquest of space are so far-reaching that an international body would seem to be essential, so great would be the need and certainly should not be impossible to create through international co-operation.

Such a body would be responsible for the good government of newly discovered planetary territories and for the overall regulation and control of all interplanetary operations, including the activities of space-vehicles and stations, under a system similar to that of the International Trusteeship System set up by the United Nations Charter and would take over and manage such territories for and in the name of the United Nations. This body would in effect be analogous to the present Trusteeship Council administering the territories through the states which may either be interested in them, or may have discovered them, or may have the greatest number of spacecraft available for communication and transport between Earth and that planet. The sanctions and laws applicable should not require to be materially different from those in existence at the present time under the United Nations Charter, and the advantage of such a scheme appears from the fact that the machinery for it is already largely in being, and does not therefore require to be created anew by what would inevitably be interminable international conferences.

The creation of a new specialized agency envisaged in Article 59 of the United Nations Charter is readily adaptable machinery for the creation of a new organization such as is here envisaged, and the rules relating to international trusteeship as contained in Articles 75 to 85 of the Charter are largely applicable to this problem.

In considering the question of disputes between states engaged in interplanetary exploration, the machinery of international justice is already to hand and should be resorted to whenever the case demands it. Besides the settlement of disputes through normal diplomatic channels and by agreement between the parties, there is both *arbitration*, which has always been a recognized method of settlement in international law, especially since the Anglo-U.S. Alabama claims in 1871 were referred to and settled by arbitration, and also *judicial settlement* by the International Court of Justice at The Hague, the modern successor to the old Permanent Court of International Justice created in 1921 under the League of Nations. The jurisdiction of this Court normally arises only when the parties have agreed to submit a dispute to it, but treaties may specify the Court as the tribunal to which all disputes arising under those treaties shall be referred.[5]

The law to be administered in the Court consists of International Conventions, whether general or particular, establishing rules expressly recognized by the contesting states—International custom, as evidence of a general practice accepted as law—The general principles of law recognized by civilized nations, and, subject to the provisions of Article 59 which deals with the effect of Court judgments, judicial decisions and the teachings of the most highly qualified jurists of the various nations, as subsidiary means for the determination of rules of law. Finally, if the parties so agree, the Court may decide the matter *ex aequo et bono*.[6]

Now this law reinforced by the great weight of precedent in international legal practice is undoubtedly what will first be used to overcome and settle the problems arising from the siting of the first space-station or the first landing upon another world, and, it is submitted, provided this new organization which we have already considered has all the authority of the United Nations behind its creation and in its operation, the legal problems of newly discovered territories and the control of space-stations do not appear to be in any way insurmountable nor even formidable. The states concerned in these enterprises will be obliged to recognize their position as trustees for the rest of the world, and severe sanctions may be imposed upon those who fail to do so, and abuse their powers.

The Spaceship

So much, therefore, for the position of states in relation to other planetary bodies or space-stations and outer space itself, but what of the spaceship, the rocket that is to venture forth, sometimes for long periods with but little restraint from Earth upon its activities?

The first point to be stressed here is the importance of insisting that every space-vehicle shall carry the flag of a particular nation, as do sea-going vessels. In this way they would come under the direct authority of their parent state which in its turn would be subject to the sanctions and controls of the specialized United Nations Agency to which I have referred before, and in default of such an organization, Articles 39 to 42 of the Charter prescribe machinery in which the Security Council may act in cases of the more serious threats to peace or acts of aggression which a piratical space-vehicle may perpetrate, and these provisions equally well apply to acts of aggression carried out by states upon or by means of a planet or moon. In more routine matters, however, the normal jurisdiction of the flag-state would seem to suffice, controlling as it does the acts of the crew, the safety of personnel aboard, navigational and communication regulations, and criminal acts committed on board.

The flag-state has certain rights and obligations in the law of the sea from which this analogy is drawn and which may be applied here with advantage. To quote from Oppenheim's International Law as to the extent of these rights: "The following rules of the Law of Nations are universally recognized, namely, first, that every state which has a maritime flag must lay down rules according to which vessels can claim to sail under its flag and must furnish such vessels with some official voucher authorizing them to make use of its flag; secondly, that every state has a right to punish all such foreign vessels as sail under its

flag without being authorized to do so; thirdly, that all vessels with their persons and goods are, whilst on the open sea, considered under the sway of the flag-state; fourthly, that every state has a right to punish piracy on the open sea even if committed by foreigners and that with a view to the extinction of piracy, men-of-war of all nations can require all suspect vessels to show their flag."[7]

One point emerges from this passage which requires some consideration in passing. It has been assumed that these spacecraft are peaceful or scientific in nature, but the possibility of the use of rockets in space to further a war upon Earth cannot be overlooked, and under those conditions such rockets and ships would be public in ownership and not private. The effect of public control of a ship in either peace or war is to compel recourse to the flag-state for redress in cases of wrong-doing or injury, since, as a rule, only a private vessel can commit piracy.[8]

The Use of the Spaceship

The contemplation of the use of space for warfare is indeed horrific, since the effects of such action upon this planet may well prove to be beyond our wildest imaginations. However, if the flag-states of two rockets or space-stations are at war with each other on the Earth, antagonism appears to be inevitable in outer space as well. Even if the use of space for conducting warfare were to be prohibited by a strong United Nations, as Oscar Schachter has suggested in an article,[3] it is obvious that rigid control of all vehicles in space would seem to be a superhuman undertaking. It must also be borne in mind that the high seas, from which we have drawn many of our analogous principles, may legally be used for belligerent purposes.

To return again to the question of normal, peaceful activities in space, the matter of communications and navigation is of supreme importance to all who will be operating in the vast unchartered realms of outer space beyond the frontiers of the Earth. Here again, the need for an efficient international system is paramount, and an organization similar to the present International Aeradio Limited, for example, which controls the wide network of many B.O.A.C. airways and airfields abroad, would seem to be demanded. No one country could undertake the enormous task of tracking and controlling its own craft, especially bearing in mind the revolutions of the Earth, which would often render visual or radio/radar contact from one state alone impossible. Such an organization, responsible to the main specialized agency already considered, would be empowered to make regulations for landing procedure, radio coding and navigational aids which would be uniform and easily applied by all travellers in space.

A considerable degree of international control could be exercised by a space-station operated by this United Nations agency, for in addition to the service it would render to the users of space as an astronomical observatory and navigational aid post, it would also act as an "eye" over the face of the Earth. By this means, an aerial survey could be conducted of all major clandestine or illegal operations in the world, since, in the "2-hour" orbit at an altitude of some 1,075 miles, an almost constant watch could be maintained over the greater part of the earth's surface. This would provide an even more effective survey

than that envisaged in the Baruch proposals of 1946 for the control of atomic energy and the making of atomic weapons.

Conclusion

A space-station is a conception with enormous potentiality, unfortunately for evil as well as for good, but that is a comment upon all propositions in the study of interplanetary flight. It is indeed a great challenge to mankind, and it is in hope for the proper regulation of the whole question that this examination of the legal aspect of the subject has been made.

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(4) J. L. Brierly, *The Law of Nations*, pp. 146–147.
(5) Statute of the International Court of Justice, Article 36.
(6) Statute of the International Court of Justice, Article 38.
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(8) Oppenheim's International Law; Lauterpacht: Vol. I, p. 559.

KNOW YOUR COUNCIL

PATRICK MOORE. Born in 1923, Patrick Moore first became interested in astronomy some seven years later, and at the age of ten became the proud possessor of a 3-in. telescope. In 1934 he was elected a member of the British Astronomical Association.

During the war he became navigator of a bomber in the R.A.F., with consequent disruption of the Allied war effort (though he always maintained that the dropping of practice bombs in a rock-garden near Barrow-in-Furness was not entirely his fault). Subsequently he became an adjutant and then an Area Meteorological Officer, but in 1945 was finally invalided from the Service, to the profound relief of certain senior officers at the Air Ministry.

Following a lengthy convalescence, he turned his attention to writing; in 1949 he published a translation from the French of De Vaucouleurs' *Problème Martien*, and this was followed, from 1951, by a series of scientific books—beginning with *Guide to the Moon*—and also boys' novels and juvenile science. He has so far written thirteen books, and threatens more.

In 1947 he acquired a 8½-in. reflector, replaced in 1951 by a 12½-in. which is erected in a small private observatory at his home in East Grinstead. He is a Fellow of the Royal Astronomical Society, a member of many British and foreign scientific societies, and has given many lectures. He is Secretary of the Lunar Section of the British Astronomical Association and has made many lunar observations with the great telescopes at Meudon and Cambridge. On one occasion he even broadcast in French, though it is understood that most listeners on the other side of the Channel thought he was speaking in German on that occasion.

He joined the B.I.S. in 1948, and became a Member of Council in 1952. Between 1952 and 1954 he also served on the Council of the B.A.A.

His other hobbies are playing the piano, chess, and bowling his weird leg-spinners in village cricket matches.

JOHN FOLEY, B.Sc. (Eng.), A.F.R.Ae.S. Born 1922, and educated at Salesian College, South Farnborough. Began an Engineering Apprenticeship at the Royal Aircraft Establishment, Farnborough, in 1939, and there obtained a Higher National Certificate in Aeronautical Engineering in 1943. Afterwards gained an Honours degree in Engineering in 1948 by part-time study at Northampton Polytechnic.

On finishing his apprenticeship he was employed at the R.A.E. on vibration and fatigue strength investigations of gas turbine and compressor blading, and transient pressure measurements. In 1946 he entered the newly formed Guided Weapons Department to work on missile stability and control, until mid-1954 when he moved to the Rocket Propulsion Department at Westcott, near Aylesbury.

He has been interested in rocket flight since he first learned of the C.B.A.S. from John Humphries, and became aware, at the end of the war, of the practical work done by the Germans on rocket development. Joined the B.I.S. in 1946, is particularly interested in rocket motors and the orbital vehicle, and hopes one day to be calculating control system parameters for a spaceship.

Interests outside the field of interplanetary flight include his work in the Low Speed Aerodynamics Research Association, where he was engaged in wind-tunnel testing and helped in the development of a radio link remote control system. May also be seen at various meetings of sports car clubs in southern England, dabbles in photography, and likes listening to all kinds of music.

D. J. CASHMORE, B.Sc. Born in 1926 in south-east London where he later attended Alleyn's School. After taking a General Science B.Sc. at King's College, London, in 1945 he joined the R.A.F. as a Radar Officer and was demobilized in 1948. Then followed four years' operational research into the use of radio aids to marine navigation as a Scientific Officer at the Ministry of Transport. In 1951 he took a Special Mathematics B.Sc. at the Polytechnic, Regent Street, and began to realize how little he knew. He is at present working as a Project Engineer designing and building electro-mechanical flight simulators and also is discovering how much more mathematics he knows nothing about by taking an M.Sc. course at Birkbeck College, London.

Mr. Cashmore's interest in space-flight (and that sort of thing) first started when he was a small boy. Even to-day he still holds dear those stories about Captain Justice in the *Modern Boy*. Soon he was having bad nights after reading about the ageless metal monster that ceaselessly roamed the airless asteroid (and similar places) in *Staggering Stories*. Nowadays it takes a lot to give him a bad night, although the H-bomb and a heavy supper sometimes manage it.

For some years Mr. Cashmore had heard vaguely about a British Interplanetary Society and in 1948, with secret excitement, applied for membership. It was with a sense of wonder that he realized that there were people in the world who would not ridicule him for having visions of the universe and the future.

It is his belief that what is required to-day is more serious study of what exactly are the aims of space-flight, what organization is necessary for the attainment of these aims, who is likely to set it up, and what sound scientific, economic and social reasons can be put forward to encourage the leaders of Government and Industry to make the huge efforts necessary for the achievement of space-flight.

He reluctantly believes that he will be too old to set foot on another world when the chance presents itself, but it is one of his cherished hopes that his son and daughter will one day see Earth as just one planet in a starry firmament.

CALCULATION OF STEP ROCKETS

By M. Vertregt.

APPENDIX

The following notes on the derivation of the equations in my previous paper, "Calculation of Step-Rockets," will probably be of interest to many members, and are therefore reproduced below.

Derivation of the Equations

From (9) $$\frac{r_1 - 1}{r_1} = \frac{m_{b1}}{M_1}.$$

From (7) $$\frac{s_1 - 1}{s_1} = \frac{\dfrac{m_{c1} + m_{b1}}{m_{c1}} - 1}{\dfrac{m_{c1} + m_{b1}}{m_{c1}}} = \frac{m_{b1}}{m_{c1} + m_{b1}}.$$

From (3) $$\frac{p_1 - 1}{p_1} = \frac{\dfrac{M_1}{m_p} - 1}{\dfrac{M_1}{m_p}} = \frac{M_1 - m_p}{M_1}.$$

From (1) $$M_1 - m_p = m_{c1} + m_{b1}.$$

Thus: $$\frac{p_1 - 1}{p_1} = \frac{m_{c1} + m_{b1}}{M_1}.$$

And: $$\frac{s_1 - 1}{s_1} \cdot \frac{p_1 - 1}{p_1} = \frac{m_{b1}}{m_{c1} + m_{b1}} \cdot \frac{m_{c1} + m_{b1}}{M_1} = \frac{m_{b1}}{M_1} = \frac{r_1 - 1}{r_1} \quad .. \quad (17)$$

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(19) $$p_1 = r_1 \cdot \frac{s_1 - 1}{s_1 - r_1}.$$

By analogy: $p_2 = r_2 \cdot \dfrac{s_2 - 1}{s_2 - r_2}$ and: $p_n = r_n \cdot \dfrac{s_n - 1}{s_n - r_n}$.

(6) $$P = p_1 \cdot p_2 \cdot \ldots \cdot p_n.$$

Thus: $$P = r_1 \cdot r_2 \cdot \ldots \cdot r_n \cdot \frac{r_1 - 1}{s_1 - r_1} \cdot \frac{s_2 - 1}{s_2 - r_2} \cdot \ldots \cdot \frac{s_n - 1}{s_n - r_n}.$$

(14) $$R = r_1 \cdot r_2 \cdot \ldots \cdot r_n.$$

Thus: $$P = R \cdot \frac{s_1 - 1}{s_1 - r_1} \cdot \frac{s_2 - 1}{s_2 - r_2} \cdot \ldots \cdot \frac{s_n - 1}{s_n - r_n} \quad .. \quad .. \quad .. \quad (24)$$

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(5) $$P = \frac{M_n}{m_p}.$$

Thus: $$M_n = m_p \cdot R \cdot \frac{s_1 - 1}{s_1 - r_1} \cdot \frac{s_2 - 1}{s_2 - r_2} \cdot \ldots \frac{s_n - 1}{s_n - r_n}. \quad \ldots \quad \ldots \quad (23)$$

From (10) $$m_{bn} = M_n \cdot \frac{r_n - 1}{r_n}.$$

Thus: $$m_{bn} = m_p \cdot R \cdot \frac{r_n - 1}{r_n} \cdot \frac{s_1 - 1}{s_1 - r_1} \cdot \frac{s_2 - 1}{s_2 - r_2} \cdot \ldots \frac{s_n - 1}{s_n - r_n}. \quad \ldots \quad (22)$$

From (8) $$m_{cn} = m_{bn} \cdot \frac{1}{s_n - 1}.$$

Thus: $$m_{cn} = m_p \cdot R \cdot \frac{r_n - 1}{r_n} \cdot \frac{s_1 - 1}{s_1 - r_1} \cdot \frac{s_2 - 1}{s_2 - r_2} \cdot \ldots \frac{1}{s_n - r_n}. \quad \ldots \quad (21)$$

From (5) $M_n = m_p \cdot P.$

Call: Total weight of structure of step-rocket: M_{cn}.
Total weight of propellants of step-rocket: M_{bn}.

Then: $M_{cn} + M_{bn} = M_n - m_p = m_p (P - 1).$

And: $$\frac{M_{cn} + M_{bn}}{M_n} = \frac{m_p (P - 1)}{m_p \cdot P} = \frac{P - 1}{P}.$$

(8) $$s_n = \frac{m_{cn} + m_{bn}}{m_{cn}}$$

When s is equal for all steps: $$s = \frac{M_{cn} + M_{bn}}{M_{cn}}.$$

Thus: $$\frac{M_{cn}}{M_n} = \frac{M_{cn}}{M_{cn} + M_{bn}} \cdot \frac{M_{cn} + M_{bn}}{M_n} = \frac{1}{s} \cdot \frac{P - 1}{P}. \quad \ldots \quad \ldots \quad (30)$$

And: $$\frac{M_{bn}}{M_n} = \frac{s - 1}{s} \cdot \frac{P - 1}{P}. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (29)$$

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ROCKET ENGINES AND PROPELLANTS*

By A. V. Cleaver, F.R.Ae.S.

Both in America and Great Britain, the term "rocket engine" is becoming more common than the older "rocket motor," which description is now tending to be used only for the solid propellant variety. However, whatever the device is called, it is (by definition) a form of reaction propulsion or jet engine in which *all* the materials (the propellants) which form the propulsive jet are carried along within the vehicle being propelled.

This is the essential difference between the rocket engine and other types, such as the turbojet, which rely on atmospheric air to provide the bulk of their exhaust mass. It is responsible for the outstanding basic characteristic of the rocket, namely its ability to maintain its thrust even in a vacuum, and so to provide a possible means of propulsion for interplanetary vehicles. Indeed, it is the only kind of engine at present known which could satisfy this requirement, in addition to its potentialities for more immediate applications to high-flying, high-speed, missiles and aircraft.

Another characteristic of the rocket type of power plant is its ability to provide very high thrust outputs for a very small size and weight of fixed apparatus. This quality, also essential for most of the applications already mentioned, makes it suitable for some other duties even though these are far removed from its normal role of high-altitude and high-speed operation. For example, rocket propulsion is suitable for any application requiring a large thrust for a relatively short period, such as the assisted take-off of aircraft. Because the rocket has to carry its own source of oxygen as well as fuel, its total consumption of propellant materials is much higher (for a given thrust) than is the case for air-breathing engines; hence it is desirable (or even only practicable, as a rule) to limit its operation to durations which tend to be measured in seconds or minutes, rather than hours.

This high consumption of the rocket power plant is, for such applications, offset by its small size and weight, which result from its use of very energetic working fluids of high density, and from its inherent simplicity. To admit that rocket engines have a high consumption for a given thrust is, of course, not to say that they are inefficient. Their thermal efficiency, defined as the ratio of jet kinetic energy to input chemical energy, is comparable to that of older types of heat engine. Also, their propulsive efficiency can be very high, if the vehicle speed is of the same order as the jet velocity; under these conditions, the rocket thrust is doing a large amount of useful propulsive work.

Solid propellant rockets are, in general, suitable only for very short burning times, although they have the advantage of the greatest possible simplicity. For longer durations, the liquid types give lower power plant weights, and also have the advantage of controllability. The casings of solid rocket tubes obviously become excessively heavy when they need to be large enough to contain a great mass of propellant, since the whole casing has to be capable of

* *This is the second in a series of introductory articles on astronautics and allied subjects,*

withstanding the combustion temperature and pressure; for such duty, the lower weight of the tanks (with a fixed size of combustion chamber) of the liquid type shows to advantage. Also, it is clearly difficult to realize in practice a solid motor capable of thrust variation, or of repeated stops and re-starts.

For both types, the following relations apply, and illustrate effectively the main qualities of rocket propulsion:—

1. $T = \frac{dM}{dt} . v_x$ (because the forward reaction simply equals the rate of change of momentum),

where T = thrust (poundals), $\frac{dM}{dt}$ = exhaust mass flow per unit time lb./sec.,

and v_x = exhaust velocity (ft./sec.).

2. S.I. = Specific Impulse (or better, Specific Thrust)

= Thrust (lb.-wt.) per unit rate of expulsion of propellant weight

$$= \frac{T}{\frac{dM}{dt}} \times \frac{1}{g} = \frac{v_x}{g}.$$

These relations apply strictly if the rocket nozzle is correctly designed to expand the gases down to the external ambient pressure. If this is not so, then a fairly small correction to the results must be applied, to allow for what is usually called the "pressure thrust" term. This is simply the difference between the nozzle exit pressure and the ambient pressure, multiplied by the nozzle exit area. It is responsible for the fact that a rocket engine, designed for correct expansion at sea level, will give between 10 and 15 per cent. *greater* thrust exhausting into a vacuum.

The internal temperature in the combustion chamber of a rocket engine is determined almost entirely by the nature of the propellants fed into it, and by their relative proportions (i.e., the mixture ratio). Typical values to-day range between 2,000 and 3,000° C. The internal pressure is determined by the mass flow rate of the propellants in relation to the nozzle throat area, and is typically between 200 and 1,000 lb./in.^{2} A convergent-divergent nozzle is employed to produce the supersonic rocket exhaust velocity, and for a fixed geometry will always produce a given nozzle exit pressure for a given propellant mass flow (and hence chamber pressure).

The outstanding design problems of rocket engines are concerned with the production of pumps, control valves, etc., of compact size and low weight, suitable for handling large flows of rather difficult fluids, which (for example) may be highly corrosive or have very low boiling points. Even more difficult is the cooling problem, associated with the provision of adequate strength in the combustion chamber containing the extremely hot gases under high pressure. Usually, one of the propellants is circulated through a coolant jacket surrounding the chamber, before its injection into this chamber for combustion.

Most of the above observations are, of course, specifically directed towards

the present-day type of rocket engine employing chemical propellants. It will be realized, however, that the term "rocket engine" should still be applied to other conceivable future types, in which nuclear or solar energy might be used as a basic source of power to accelerate a mass of material comprising a propulsive jet.

For any conceivable kind of rocket engine using thermal energy directly, the most fundamental performance equation is:—

$$3. \qquad v_x = \sqrt{\frac{2\gamma}{(\gamma - 1)} \cdot \frac{G\theta_o}{M} \cdot g \left\{ 1 - \left(\frac{P_x}{P_o} \right)^{\frac{\gamma - 1}{\gamma}} \right\}}$$

where P_x and P_o are the pressures (lb./ft.^{2}) at the nozzle exit and in the combustion chamber, respectively: θ_o is the combustion temperature in ° C. absolute: G is the universal gas constant, in ft.-lb./lb. mol./° C.; and γ and M are the mean values, respectively, of the specific heat ratio and the molecular weight, for the exhaust gases.

This expression (3) can be derived from considerations of momentum and the adiabatic expansion of the gases between the chamber and the nozzle exit. It is worth some study, for it tells us quite a lot about the fundamentals of rocket propulsion.

In the first place, part of the expression, i.e.:—

$$E = \frac{\gamma}{(\gamma - 1)} \cdot \frac{G\theta_o}{M}$$

is equal to the calorific value, or total theoretical energy content, of the propellants, in ft.-lb. per lb. wt. If this quantity is called E, readers will probably recollect often having seen the expression:—

$$4. \qquad v_i = \sqrt{2Eg.}$$

where v_i has been called the "ideal" exhaust velocity. It is, in fact, the value which the exhaust velocity would have if *all* the energy of the propellants could be converted into jet kinetic energy. In practice, this cannot be done; if the exhaust gases are expanded over a given finite pressure ratio (P_o to P_x), then there is a theoretical upper limit to the amount of energy which can be extracted from them.

This upper limit is given by the theoretical efficiency of the thermal cycle involved, i.e. by:—

$$\left\{ 1 - \left(\frac{P_x}{P_o} \right)^{\frac{\gamma - 1}{\gamma}} \right\}$$

It will now be realized that the "ideal" exhaust velocity, v_i, really has very little practical significance. To obtain the true theoretical value, the complete expression (3) must be used, including the cycle efficiency term. In practice again, there will be inevitable losses from nozzle friction and shock, incomplete combustion, etc. As a result of these, the actual exhaust velocity will usually be some 5 per cent. lower than that calculated from (3).

The second important conclusion to be drawn from equation (3) is that, for given conditions of temperature and pressure in the engine, $v_x \propto \sqrt{\frac{1}{M}}$.

That is, other things being equal, it will always pay to seek propellants which give light gases (of low molecular weight) as their exhaust products. (The effect of γ is very small.)

Readers will recall, from their school chemistry, Avogado's Hypothesis, which states that a given weight of gases, at a given temperature and pressure, occupy a volume inversely proportional to their molecular weight. There are always the same number of molecules in a given volume, for these conditions, so the lighter gases (with more molecules per lb. total wt. of gases) will expand to fill a larger volume. This happens in the rocket engine: in their effort to expand to this larger volume, they rush out of the nozzle with a higher velocity.

Rocket Propellants

The term "rocket propellants" includes all the materials making up the reaction mass expelled in the exhaust of a rocket.

In a hypothetical atomic rocket of the future, these might consist merely of an inert mass of working fluid (maybe even water, heated up and ejected as steam), or even of a beam of charged particles (ionised atoms or molecules, or sub-atomic particles). In the chemical rockets of to-day, the propellants consist of one or more chemical compounds or mixtures, which are made to react and release their energy in the chamber of the rocket power plants.

It is important to realize that *any* chemical reaction which releases energy and provides gaseous products can form the basis of a rocket propulsion system. In most practical cases, the chemical reactions actually employed involve the combustion of fuels (containing the elements carbon and/or hydrogen) in oxygen. The oxygen may be carried initially (i.e. before combustion) in a compound or mixture in association with the fuel; in this case, one would have a "monopropellant" system. Alternatively, and more usually, the oxygen may be provided from a second fluid, called the "oxidiser" or "oxidant"; this is a "bi-propellant" system.

However, such cases by no means exhaust all the possibilities. For example, there are monopropellants, such as hydrogen peroxide, which can be made merely to decompose and release hot gaseous products, thus providing a rocket jet. Since these products, in this particular case, consist of steam and oxygen, it is also apparent that a second fluid (a separate fuel, which could be of higher potential energy) can be made to react additionally with this oxygen, so increasing the performance. Hydrogen peroxide is therefore a rocket propellant which is both a monopropellant fuel in its own right, and also an oxidant for use with other fuels.

Hydrazine is a fuel which can be burned with other oxidants, but which can also be made to decompose (into nitrogen and hydrogen), with release of energy, by itself. It also is therefore a monopropellant.

Fuels can also be made to react with fluorine (or fluorine compounds or mixtures), instead of with oxygen (or oxygen compounds or mixtures). Indeed, the energy release for many such reactions is even larger than for the oxygen case, so that the potential rocket performance is even greater, if the many severe practical difficulties can be overcome.

Solid propellants, such as gunpowder or cordite, are obviously monopropellants, in which the fuel and oxidant are combined in a single chemical mixture before the reaction is initiated. There are also many liquid compounds (such as nitromethane), and mixtures (any fuel with any oxidant, in theory, providing they do not react spontaneously), which can be used as monopropellants.

Liquid monopropellants, in particular, usually have to be handled with care; there is an obvious potential danger in having all the materials, which are capable of reaction, in intimate association before their injection into the chamber. Indeed, it should be mentioned that the handling of *all* rocket propellants is a thing to be approached with care and to be undertaken only by well-qualified or suitably-trained individuals, especially in the experimental stages.

In general, the best liquid propellants have a higher performance than the best solids, though there is a considerable overlap in the whole range. Readers will recall the experiments of the Pacific Rocket Society with combined bipropellant systems, in which a solid fuel was built into the chamber, ready for combustion with a liquid oxidant. This is yet another of the many possibilities.

Having discussed a number of these, it remains to state that the great majority of present rockets of interest to B.I.S. members employ liquid bipropellant systems. In these, a fuel (such as alcohol, kerosine or gasoline) is burnt with an oxidant (such as liquid oxygen, hydrogen peroxide, or nitric acid). These two propellants have to be ignited, for example, by a source of heat (such as a cartridge) or a spark plug. A variant of this system is to employ what the Germans called a hypergolic fuel, which is self-igniting with the particular oxidant used. An example of such a pair is aniline, with nitric acid.

Most of the above propellant systems, applied with reasonable efficiency in the rocket engine, give a specific impulse of between 200 and 250 secs. This is unlikely to be even as much as doubled in any future chemical propellant system, using natural fluids. The possibilities of producing synthetic substances of greater latent energy, or of obtaining stable mon-atomic hydrogen as a monopropellant, must be regarded as conjectural. The best hopes of improved performance would seem to lie in the direction of utilizing nuclear energy.

In deciding the propellants to be used for any particular rocket project, there are obviously a great many considerations involved. Among these may be mentioned: performance; cost; availability; ease of handling; ability to store in tanks for relatively long periods, either in the vehicle or on the ground; density, as affecting required tankage volume, and therefore drag and weight of vehicle. All these factors have relatively different degrees of importance for rocket vehicles required to perform different duties. This explains the great variety of propellants employed, since it results in the conclusion that there is no ideal single solution to the problem.

References

For further and more detailed study, the reader is referred to *Interplanetary Flight* (Clarke: Temple Press or Harper Bros.) and *Rocket Propulsion Elements* (Sutton: Chapman and Hall or John Wiley.)

USING HYDROGEN PEROXIDE

By A. V. Cleaver, F.R.Ae.S.

(*A paper read to the British Interplanetary Society in London, January* 8, 1954.)

Introduction

When considering any rocket project, the choice of propellents is the first, and probably the most important, decision that has to be taken. There is no such thing as a universal best choice of propellent, the various alternatives all having their pros and cons, and these having different degrees of desirability or otherwise for different applications. In short, the choice of propellent has to be related to the required duty. Such a situation is very familiar to any engineer; indeed, it is an almost universal state of affairs.

The difficulties involved in making the propellent choice are more usually concerned with the oxidant (the source of oxygen) than with the fuel (the source of energy). Hydrogen peroxide is unusual in being a low-energy fuel in its own right (i.e., a monopropellent) as well as being an oxidant. For this and a number of other reasons it has outstanding advantages as a rocket propellent for many purposes.

Method of Manufacture

Hydrogen peroxide has been used in industry for just over seventy years, but most of that time its main use was as a bleaching chemical and it was manufactured in strengths normally up to only 35 per cent. During recent years the position has altered considerably and developments throughout the world have resulted in the production of hydrogen peroxide up to 90 per cent. strength, known as high-test peroxide or H.T.P., of such purity and stability that it can be stored, handled and used as a convenient and potent source of energy for power units. This development is of particular interest for aircraft and naval developments. It is a clear liquid resembling water in appearance, is not highly corrosive or fugitive in nature, and physiologically is not seriously dangerous, so handling it is not difficult.

The method of manufacture has been an electrolytic one via persulphates, but there have been recent developments in autoxidation processes, as, for example, one using ethylanthraquinone and another using para-azotoluene. Work has also been published on the production of peroxides by the oxidation of hydrogen and hydrocarbons. With these new processes being tried out, it will be interesting to see which will survive, but there are indications that the cost of production will be much reduced, and certainly more than halved. For security reasons, not very much can be said about the plans under way for producing hydrogen peroxide in large quantities, but far-seeing and elaborate schemes are afoot.

In a rocket engine, hydrogen peroxide is used by decomposing the liquid H_2O_2 into oxygen (O_2) and steam (H_2O). A fuel can be burnt in the oxygen to raise the temperature of the products and increase the specific impulse.

Hydrogen peroxide can be catalysed by such materials as the liquid

permanganates and silver, lead, copper and platinum, and upon catalysis decomposes to form steam (H_2O) and oxygen gas (O_2). To-day's technique of using one of the metals means that a separate tank for a liquid catalyst is no longer required, as was the case during early development.

Choice of Propellent

The characteristics of hydrogen peroxide have outstanding advantages when compared with the two other common oxidants, liquid oxygen and nitric acid, particularly for use in rocket engines installed in operational aircraft. The reasons for this can be summarized as follows:—

(*a*) H.T.P. is a fuel in its own right and can be used as a monopropellent after catalysis. This is particularly of importance for driving auxiliary equipment and for repeated engine starting.

(*b*) H.T.P. has a high relative density. This allows more propellent to be carried for a given aircraft tankage volume than in the case of liquid oxygen, and, moreover, no tank lagging is required.

(*c*) H.T.P. has good safety qualities. By arrangement, the peroxide can be decomposed before fuel is admitted to the combustion chamber. Thus the chamber is first purged with steam and it is almost impossible for fuel to accumulate in the combustion chamber at any time. Thus the risk of an explosion, the greatest danger with rockets, is greatly reduced.

(*d*) H.T.P. can be stored and handled very easily. There is virtually no evaporation loss, and only elementary precautions are necessary when handling.

(*e*) Engine simplicity. No separate ignition or starting systems and no separate auxiliary drive systems are required.

(*f*) Low combustion temperatures with a given fuel ease cooling problems and lead to increased safety and longer engine life.

Although nitric acid has some attractive qualities, including an even higher density than peroxide, has none of the low temperature problems of liquid oxygen, and is cheap to produce, its use is not desirable because of its very acute corrosion and sealing problems and the extreme difficulty of handling it safely without elaborate and inconvenient precautions. Liquid oxygen suffers from the severe disadvantage of a boiling point of −183° C.

Fuels used with Hydrogen Peroxide

With H.T.P. two classes of fuel may be used:

(*a*) a hypergolic fuel that initiates spontaneous combustion as soon as it comes in contact with H.T.P., such as the German "C-stoff" (57 per cent. methanol, 30 per cent. hydrazine hydrate, 13 per cent. water and 0·3 per cent. potassium cuprocyanide as a catalyst);

or (*b*) a fuel that will not initiate spontaneous combustion unless the H.T.P. is catalysed beforehand. Examples of this kind of fuel are kerosine or gasoline.

Operational Advantages

The stability and negligible evaporation losses of hydrogen peroxide make it especially suitable for use in rockets for assisted take-off. The rocket unit can be fuelled and even placed inside a suitable container, if it is attached externally to the aircraft, long before being required. The same advantage is also applicable to rocket-powered fighters which will be required to wait at the ready—perhaps for many hours before warning is received of raiders.

One of H.T.P.'s advantages over liquid oxygen and nitric acid is its ease of storage. Liquid oxygen, with a boiling point of −183° C., is subject to rapid evaporation, which can only be reduced to manageable proportions by elaborate lagging of tanks and by frequent topping-up.

Nitric acid is extremely corrosive and subject to loss in strength due to both chemical and hygroscopic action.

The H.T.P. now manufactured is so pure and stable that it will run down in strength by only about 1 per cent. per year if stored in suitable tanks in temperate climates; the loss might be increased to 2 or 3 per cent. at tropical temperatures. Such loss of strength means that the peroxide is decomposing to form oxygen and water as products. For this reason storage tanks should be vented to permit, not only the release of the small amount of oxygen gas, but to cater also for larger quantities of gas in an emergency. Such vents should incorporate traps to prevent the ingress of dust or other foreign bodies. Since peroxide is a fuel in its own right, energy is also being released in the form of heat, but because of the very slow rate of decomposition, this is no embarrassment. If peroxide is heated much above 60° C. the rate of decomposition increases, although not dangerously, until the temperatures are very considerably higher.

A good material for long-period storage tanks is pure aluminium, which is quite inert; many aluminium alloys and most stainless steels are very inactive when correctly prepared and are suitable for medium-period H.T.P. containers or other apparatus.

Handling

The handling of H.T.P. presents a problem no more insuperable than other technical innovations have in the past. For example, ordinary de Havilland works personnel have handled it on a fairly large scale for several years and have not had to be subjected to any excessive amount of training or supervision. This experience shows that peroxide can be handled in the field just as easily as petrol by observing a few sensible precautions.

A high standard of cleanliness is essential. There is an inherent fire risk with all oxidants, and in the case of H.T.P. this is largely due to the possibility of dirt or foreign bodies being active catalytic materials, which would increase the rate of decomposition of the peroxide possibly to an extent permitting it to ignite other inflammable materials.

It is as well to state what such an unlikely emergency might consist of; the possibility of peroxide exploding is quite negligible since, although the highest strength of peroxide can be detonated in a laboratory, this can be done only under special conditions, which could not arise on a storage site.

In the event of very rapid decomposition of the peroxide, steam and oxygen might be evolved at such a rate as to cause a pressure burst of a tank, but only if it had been inadequately vented. Decomposition at any undesirable rate, of course, could occur only if some proportionately large quantity of foreign catalytic matter had got into the tank, or if the tank was in a building that was itself on fire from other causes. In extreme cases the peroxide might all boil away, but in most cases control of the liquid could be regained before this by adding stabilizing fluid, or by water dilution, and in all cases the incident in all probability would be spread over a matter of hours, if not days. No such experience has ever occurred at de Havilland's, and very few elsewhere. One of the latter was discovered only after a month or so storage, and was due to a large copper object having been dropped into an H.T.P. tank.

Water is the one antidote which should never be absent from any site where peroxide is handled, because peroxide is quite innocuous if diluted below about 50 per cent. strength. In higher strengths H.T.P., although non-inflammable itself, will decompose if it falls on wood, clothes or rags, particularly if these are not clean, so evolving an oxygen atmosphere and possibly enough heat eventually to ignite the secondary material. Small drips or leaks are not really serious, as they will merely steam off the surfaces on which they fall.

Any accidental intimate mixture of peroxide (as for other oxidants) with a high energy fuel (such as petrol) should be carefully avoided. Such a mixture will not react spontaneously like peroxide and "C-stoff," but it does constitute a potential explosive risk, since it might be set off by some external agency.

There is, of course, a good case for carrying out peroxide transfer operations under self-contained conditions, using special refuelling equipment, hoses with self-sealing couplings, etc. A similar trend is evidenced in the modern technique for handling all liquid fuels, and if followed for H.T.P., any of the risks described can very conveniently be avoided. Such a system was designed and developed for refuelling the Sprite A.T.O. unit when installed in the Comet aircraft, and it has been used very successfully.

Protective suits of a suitable plastic (which are made by several firms and closely resemble ordinary lightweight overalls) are essential to eliminate fire risk to normal clothing, and also to prevent skin burns from splashing. Such burns can be painful, but are not dangerous. If the affected part is immediately washed with water no mark will result. If this is not done, the skin will suffer a chemical burn, leaving bleach marks which will last for a few hours.

By way of comparison, handling difficulties with liquid oxygen are considered to be as great as with H.T.P., and centre mainly on the fire risk caused by the constant evaporation; this produces a highly oxygenated atmosphere in which other materials will readily ignite by means of sparks struck from boots or tools, for instance. The difficulties with nitric acid are considerably greater, due to its corrosive effects, and because of the risk to personnel of serious chemical burns, which are liable to become septic.

Safety and Reliability

A high energy fuel, such as kerosine or gasoline, is not spontaneously

combustible with hydrogen peroxide liquid, but if the peroxide is catalysed and the kerosine then injected into the combustion chamber in a finely atomized spray, then automatic ignition will occur in the hot gaseous products (steam and oxygen). This provides absolutely safe and automatic thermal ignition and obviates the necessity for any separate electrical or other kind of ignition system. The safety feature of this system cannot be over-emphasized as it removes one of the major hazards of rocket motor operation. The gaseous peroxide products constitute a fool-proof purge preventing the accumulation of any fuel in the chamber in the event of an ignition delay.

Aircraft Design Considerations

H.T.P. (sp.gr. = 1·35) is denser than liquid oxygen (sp.gr. = 1·13) though not as dense as nitric acid (sp.gr. = 1·52), and the total propellent tankage volume required with oxygen as the oxidant would be more than 20 per cent. greater than with peroxide. This would be reflected in increased airframe weight and wetted area (if not frontal area also) and these factors must inevitably result in some loss of performance. On top of all this, to reduce evaporative losses to something like manageable proportions, the oxygen tanks have to be surrounded by a thick layer of lagging, occupying still further volume.

Because of the nature of the fluid concerned, the tankage and plumbing systems would also be heavier and more complicated for liquid oxygen than for peroxide. The tanks are likely to be more heavily pressurized and to need separate booster pumps.

The main source of fire risk is through spillage in dirty or oily cowlings, or on the ground. The fact that fuel and oxidant are not spontaneously combustible appreciably reduces the danger, but the cowlings should be kept clean. Leakage from pipe joints or tanks will not constitute a danger if the components concerned are adequately drained. If some peroxide is spilt either on the ground or in the cowling or airframe and starts to decompose, water should be poured on it and all danger will be averted.

Use as a Monopropellent

H.T.P. is used primarily as the oxidant in a bi-propellent or "hot" rocket motor. As already stated, it is, however, also a fuel in its own right and may be used alone in a so-called "cold" rocket like the de Havilland Sprite assisted take-off motor, by being passed through a gauze decomposer for instance. When catalysed, H.T.P. decomposes with a release of energy and a temperature rise to form oxygen gas and steam, but the decomposition reaction does not, in fact, make full use of the chemical energy inherent in the H_2O_2 molecule. The thrust output of a "cold" rocket is only about half that of an equivalent "hot" rocket, using the same amount of peroxide but burning another fuel in the oxygen released by the peroxide. In other words, a "hot" peroxide rocket could be run "cold" as an alternative, on peroxide only, with reduced thrust.

Auxiliary Services

There are, however, other advantages to be gained from hydrogen peroxide. The pressure and temperature generated as part of the decomposition reaction

can be harnessed to provide both an engine starting system and an auxiliary drive system without resorting to any outside form of energy. A likely method of driving the auxiliary equipment would be by means of a low temperature turbine, as in the German V2, in which peroxide was carried for this purpose even though the main propellents were alcohol and liquid oxygen. This practice has also been followed in the rocket power plants of the Bell X–1 and the Douglas "Skyrocket," the Martin "Viking" and other rocket aircraft and missiles.

Engine Simplicity

All the major auxiliary services are thus very simply dealt with without any secondary supply of power being required. None of these services can be supplied on a liquid oxygen or nitric acid motor without recourse to far greater complication and novelty, and even so, the final designs by their very nature must be inherently less foolproof.

Materials

The relatively low combustion temperatures of the peroxide engine also have considerable advantages in their effect on reliability, long engine life and safety. The combustion chamber itself will stand up to repeated use for a considerable period of time. Moreover, the simplicity of the engine as a whole will lead to reliability in operation.

Care has to be taken with the materials used in the construction of peroxide tanks, pipelines and cocks. There is now enough experience with various metal and plastic constructional materials in contact with peroxide to say that no serious difficulties exist in this direction. Here again, however, the difficulties experienced with both liquid oxygen (mainly due to the embrittlement of all materials at the extremely low temperature) and nitric acid, with its acute corrosion and sealing problems, are considerably greater than in the case of H.T.P. Though slightly corrosive, the main problem with H.T.P. is merely that of keeping it away from active or catalytic materials, which has been mentioned previously.

In conclusion, the author would like to express his gratitude to the de Havilland Engine Co., Ltd. for permission to give this short paper.

ROCKET POSTCARDS

A set of six rocket postcards, size 4⅛ in. by 5⅞ in. are available at 3s. per set, post free.

They comprise the following:—

(*a*) "Viking" No. 9.

(*b*) Experimental "Hermes" rocket missile.

(*c*) "Viking" being fired at White Sands.

(*d*) WAC-Corporal and V2 booster rocket.

(*e*) "Viking" in firing position.

(*f*) WAC-Corporal and launching tower.

Orders (with remittances) should be sent to the B.I.S. Secretary, 12, Bessborough Gardens, London, S.W.1.

LIQUID OXYGEN AS A ROCKET PROPELLANT

By S. Allen, M.I.Mech.E., A.F.R.Ae.S.

Production

Liquid oxygen is a pale blue liquid which boils at — 183° C. at atmospheric pressure. It has a specific gravity of 1·14, a specific heat of 0·395 cal./gm., and its latent heat of evaporation is 51 cal./gm.

It is produced in bulk by the distillation of liquid air, the resulting liquid oxygen having a purity of > 99 per cent., the impurity consisting almost entirely of nitrogen.

The plant required for the production of liquid oxygen consists essentially of air compressors, heat exchangers and distillation columns. The raw material, air, is obtainable in large quantities everywhere on the earth's surface, and thus liquid oxygen can be produced wherever adequate power supplies exist.

Using modern machinery in a stationary plant the energy absorbed in producing one ton of liquid oxygen would be 950 to 1,000 kw. hr. A mobile plant would almost certainly be less efficient, and would probably use a gas turbine as the source of power.

LO_2 is produced at present at the rate of about 300,000 tons a year, and sells at about £10 to £20 per ton delivered according to quantity. It is possible that if the present demand for LO_2, which is mainly absorbed by the steel and engineering industries, were to be considerably increased by its large scale use in rockets, the price could be further reduced.

Storage

Due to its very low boiling point liquid oxygen suffers a constant loss by evaporation when stored at atmospheric pressure. This loss can be reduced to very small proportions by adequate insulation, which is easy to provide on large stationary storage tanks, and can also be provided on road tankers. It is not so easy to provide on rocket tanks, and storage in the actual rocket vehicle using the best conventional insulant usually entails losses of the order of 1 to 3 per cent. per hour for a thickness of lagging of 1 in., while within the earth's atmosphere. In space, of course, the loss could be cut to negligible proportions.

By using a vacuum-walled tank of about the same bulk as a lagged tank the losses from the rocket vehicle tank can be reduced to about 12 per cent. per day, although the weight of the tank would be approximately doubled.

For bulk storage, tanks are already in existence which have the following characteristics:—

Tank size.	*Loss.*
13 tons	2·5 per cent. per day
80 tons	0·6 per cent. per day

For transport, road tankers are used:—

Capacity.	*Losses per cent. per day.*
4 tons	4·5 per cent. stationary, 6 per cent. running
8 tons	3 per cent. stationary 4 per cent. running

Handling

The liquid oxygen tank of the rocket vehicle will presumably be at atmospheric temperature before it is filled. In order to cool the tank to the temperature of liquid oxygen a certain amount of the liquid oxygen will be boiled off. This amount will be given by:—

$$\text{Weight of tank} \times \text{specific heat of metal} \times 3{\cdot}88$$

Taking as an example an aluminium tank of 600 gallons capacity weighing 300 lb. the loss in cooling the tank would be about 4 per cent. A further loss will be entailed in cooling the pipes, pumps and valves of the rocket engine.

This loss can be largely avoided if the liquid oxygen in undercooled, i.e., cooled below its boiling point at atmospheric pressure. Again taking the 600-gallon tank as an example, and assuming a loss of 3 per cent. per hour under normal conditions, if the liquid oxygen is undercooled 10° C., a small amount of evaporation will occur during filling and no evaporation will occur for just over 80 minutes after filling. It will, of course, be necessary to provide the plant and power supply for the undercooling, and whether it will be more economic to undercool or to make up the losses is a matter which can only be decided when the exact circumstances of the application are known. The same applies to large bulk storage tanks.

The hazards involved in handling liquid oxygen are slight, the main danger being frost-bite, from touching pipes containing liquid oxygen. This, however, can be avoided by wearing asbestos gloves. Liquid oxygen will not cause ignition of inflammable materials, but once a fire has started combustion becomes vigorous. Mixtures of inflammable vapours and oxygen are very dangerous, as are, of course, mixtures of inflammable vapours and air. In general, the safety precautions normally taken for petrol are adequate for liquid oxygen.

Due to the low boiling point of liquid oxygen, the piping system must be so designed that no liquid can be trapped in a sealed space, e.g., between two cocks, as otherwise the liquid will take up heat from its surroundings, boil, and burst the pipe.

Filling of an aircraft or other rocket vehicle with liquid oxygen can be carried out normally as with any other fuel. If necessary, pressure refuelling can be used.

Performance

The performance of liquid oxygen as the oxidant in a propellant combination depends, of course, to some extent on the fuel chosen. In general, it can be said that, of the oxidants which are obtainable in practical quantities, oxygen gives the highest performance on a weight basis with any given fuel. In combination with kerosine the theoretical specific impulse, that is the thrust obtained for the expenditure of 1 lb. of propellant per second, is 250 at an expansion ratio of 20 : 1 and 275 at an expansion ratio of 40 : 1. If liquid hydrogen is used as the fuel the S.I. increases to a maximum of 345 at a ratio of 3 oxygen to 1 of hydrogen, using an expansion ratio of 20 : 1.

In the case of kerosine the flame temperature will be of the order of

3000° C., which introduces some cooling problems. In the case of hydrogen the maximum S.I. is obtained at a mixture ratio far removed from that giving the maximum flame temperature, the flame temperature at an oxidant to fuel ratio of 3 being about 2200° C. However, the maximum flame temperature obtainable from a oxygen/hydrogen combination is about 3200° C., and it is possible that such a temperature could be obtained locally in the combustion chamber due to non-homogeneity of the charge, or of course due to metering errors.

Although the S.I., obtainable from oxygen/fuel propellant combinations is high on a weight basis, on a volume basis it is lower than that obtained with hydrogen peroxide and with nitric acid combinations.

Influence on rocket engine design

The main influence of liquid oxygen on the rocket engine design is due to its very low temperature and its tendency to evaporate. Its strongly oxidising properties are shared with other oxidants.

Liquid oxygen is non-corrosive and no special measures are needed in this respect. There is a wide choice of metals for construction. The only common metal which must be avoided is mild steel, which suffers severe embrittlement at the temperatures of liquid oxygen. The properties of many stainless steel and aluminium alloys are improved at these low temperatures. Unfortunately, it is seldom possible to take advantage of this because, usually, components are subjected to their working stresses before they have had time to cool. Most organic materials and plastics suffer severe embrittlement when in contact with liquid oxygen, which poses problems in seal design, but these problems can be solved. One seal material which has been found to be quite successful is water-dressed leather, impregnated with beeswax.

Surfaces where friction can occur should be of bronze or stainless steel; heavy friction on aluminium alloy surfaces in the presence of oxygen can lead to fires. For this reason pump bodies are either lined with or made of stainless steel, with a bronze or stainless steel rotor. Although normally the pump body and rotor do not come into contact, this could happen accidentally.

Control valves are of the normal "poppet" type, operated by air or nitrogen pressure. The only special feature here are the stem and piston seals.

The pumping of liquid oxygen to high pressures presents no real difficulties. All that has to be done is to ensure that from the storage tank onwards the pressure rises at a rate which will raise the boiling point of the liquid oxygen faster than its temperature is raised by conduction of heat from the surroundings. In order to suppress any boiling whatever in the suction pipe, a booster pump giving a pressure rise of a few p.s.i. can be fitted immediately on to the tank or may be even immersed in the tank. On the other hand, provided the running time of the rocket engine is limited to a few minutes boiling can be suppressed by pressurizing the liquid oxygen tank to a few p.s.i. The running time at this condition is limited because the liquid in the tank will be gradually taking up heat and will eventually reach its boiling point at the higher pressure.

As for other oxidants, the centrifugal pump is the best means of pumping

liquid oxygen in the quantity and to the head required by the rocket. Means of insulating the lubricated bearings both thermally and geographically from the oxygen must be provided.

The flow of liquid oxygen can be measured conveniently by a flowmeter. In this a rotor is driven by the liquid oxygen flow and the rate of turning of the rotor is measured electronically.

Conclusion

Liquid oxygen, because of its ease of handling, low cost, and convenience of manufacture is probably the best oxidant to use for the propulsion systems of large guided missiles.

Its use in aircraft has already been proved; its greater bulk compared with that of other oxidants is a disadvantage in very high performance fighters, but whether this disdavantage is outweighed by its advantages in other respects can only be shown by experience.

For space flight, oxygen propellant combinations are the best of a poor choice of chemical propellants. They are only exceeded in performance by fluorine combinations and ozone combinations. Both of the latter have very unpleasant habits.

In conclusion, I should like to thank Armstrong Siddeley Motors for permission to give this talk.

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NOTES AND NEWS

B.I.S. Badge

There was a good response to the request in the May, 1954 *Journal* for suggested designs for a B.I.S. Badge: in all 73 designs were received from 46 members. At a recent Council meeting these various designs were carefully considered, and after eliminating those considered unsuitable for one reason or another, designs submitted by the following members were placed on a short list: K. H. Couch, D. Hicks, M. Laurie, A. Mason, A. Roden, D. C. Rowe, O. Schwiglhofer, R. Turner and R. O. Woods. The badge finally selected was that proposed by Mr. A. Mason, and his drawing is reproduced here; one of the twelve designs submitted by Mr. K. H. Couch was the runner-up. Gifts of membership subscriptions have been made to these two members as a token of the Society's gratitude, but the Council also wishes to express its thanks to all who sent drawings or suggestions.

Where questions of artistic taste are concerned differences of opinion are bound to arise, and whatever the badge selected it would be almost inevitable that there would be some criticism, but it is hoped that the approved badge will find acceptance amongst the majority of members. It was of course possible to approve only one design, and it should not be thought that the other entries were considered to be without merit. They did vary widely in quality, both in design and in execution, although the quality of the draughtsmanship did not influence the Council in its consideration of any design. The principles guiding its decisions were:

(*a*) The badge should not be too large, and hence should not contain too much detail or small lettering.

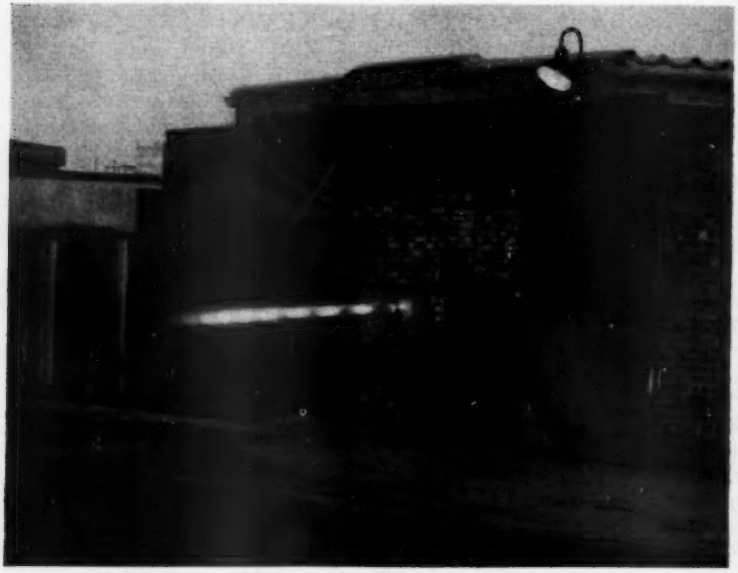
(*b*) The design should be relevant to Astronautics. At least one of the entries was so abstract that it would do as a badge for any organization whatsoever. This had to be rejected, although quite pleasing to the eye.

(*c*) The badge should be neat and simple, rather than of the gaudy type which one tends to associate with children's comics or soap manufacturers' gifts.

(*d*) The rocket depicted should be as abstract as possible, to guard against non-members supposing that it was an approved design for a spaceship.

(*e*) Last, but by no means least, if the Society were not to incur a financial loss, the cost of the finished badge must be kept down to a sum which all members could afford to pay. Some of the designs submitted (e.g., those of Mr. Turner, which were of great artistic merit) had to be dismissed because the cost of manufacture would be too great, particularly in view of the comparatively small numbers that would be required.

Arrangements are now being made for the badge to be manufactured and it is expected to become generally available at the end of May, price 4/6d. each post free. Orders may be placed with the B.I.S. Secretary now, stating whether a stud or brooch type badge is required.



D.H. 8322

The Super Sprite assisted-take-off rocket engine on test. Clearly visible is the characteristic supersonic shock-wave pattern in the rocket exhaust.

Personal

We are pleased to record the appointment of Mr. A. V. Cleaver, F.R.Ae.S., as Chief Engineer (Rockets) to the newly-formed Rocket Division of the De Havilland Engine Co., Ltd., with Mr. W. N. Neat, B.A., A.F.R.Ae.S., as his deputy.

Both Mr. Cleaver and Mr. Neat have served on the Society's Council, and were directly concerned with the development of the de Havilland Super Sprite, the first British rocket engine to secure a Government Type Test Certificate clearing it for quantity production. Their team includes a good number of other B.I.S. members.

Details of the Super Sprite are still restricted, but it is known to employ hydrogen peroxide in conjunction with a solid metal catalyst and its thrust is augmented by the after-burning of kerosine or gasoline fuel. It gives 120,000 lb./sec. of total impulse, with a maximum thrust of 4,200 lb. and a total duration of 40 seconds. It has a dry weight of 620 lb., and is mainly intended as an ATO unit for large aircraft. It may be employed either as a fixed installation in the aircraft, or jettisoned by parachute for subsequent recovery after take-off.

De Havilland began rocket development work about nine years ago and work announced to date has been concerned with ATO units, but it is of

interest to note that the Chairman of the Company mentioned in April, 1953, that activities were not limited to this type of unit and that rocket engines as main power units provided a field of great opportunity.

IAF Congress in Copenhagen, 1955

The Secretary would be very interested in hearing from those members who hope to be present at the IAF Congress to be held in Copenhagen from August 1 to 8, 1955.

Accommodation can be booked through the Danish Interplanetary Society, P.O. Box 31, Copenhagen, K, Denmark, and early application is advisable.

Western Branch

It is very pleasing to record that, at the meeting of the Council on February 5 it was resolved that the Provisional Western Branch of the Society now be established on a permanent basis.

The officers of the Branch, who have put in so much work during the past two years are to be congratulated on their endeavours, and it is hoped that the Branch will continue to enjoy the support of its local membership and proceed from strength to strength in its subsequent consolidation.

Technical Study Groups

The Council would like to ascertain the degree of support for a suggestion for the formation of Technical Study Groups which was put forward at the Ninth Annual General Meeting.

Groups of this sort have previously existed within the B.I.S., but have never been wholly satisfactory, and although a determined attempt to form such groups covering a number of fields was undertaken in the years 1946-48, the response was poor.

Members interested are asked to write to the B.I.S. Secretary giving details of their particular interests, qualifications, etc., and the degree to which they are prepared to extend their support to such groups, if they were formed.

In the first instance, action will be restricted merely to collecting particulars of the members interested in this matter, in order that further consideration may be given to it by the Council and definite terms of reference decided upon.

Informal Meetings

The Council would like to provide facilities for informal meetings between members during the summer months, as it is felt that there is quite a real need for such functions.

Accordingly, it has been decided to introduce this as a regular feature during our present "closed" session, and the first meetings have been arranged for the following dates, beginning at about 7.30 p.m.

June 4; July 2; August 20.

All meetings will be held at the Masons Arms, Maddox Street (off Regent Street), London, W.1.

No fixed agenda will be decided upon and members are free to come and go as they please.

Members of the Council and other leading Fellows of the Society will be available to discuss topics of mutual interest, and every opportunity will be afforded for members to get to know each other.

South African Interplanetary Society Exhibition

Much interest was aroused at the Exhibition put on recently in Johannesburg by the South African Interplanetary Society in conjunction with Astronomical Society of South Africa.

A number of large photographs, many drawings and seven models, including those of a Viking, and V2/WAC Corporal made up the body of the exhibits, together with a selection of publications available for those interested in the subject.

Five postcard-size photographs of some of the exhibits are available price 1/- each from the Secretary, S.A. Interplanetary Society, P.O. Box 2330, Johannesburg.

Design for B.I.S. Gold Medal

Members are invited to submit designs for a B.I.S. Gold Medal which the Society could award as occasion arises in recognition of original research which significantly advances the attainment of our ultimate objective of space-flight.

The Medal is to be awarded by vote of the Council, and all B.I.S. members may bring to their attention details of any individuals who, in their opinion, might qualify for such an award.

List of Photographs available to Members

A list of photographs available for purchase through the Society can be obtained free of charge on writing to the B.I.S. Secretary, 12, Bessborough Gardens, London, S.W.1.

Prizegiving

A report from America states that a ten year old schoolboy recently won a competition for naming an imaginery planet.

The prize was a five ton toy space ship, 32 ft. long, and with room for a crew of eight.

Sky and TELESCOPE

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DATA SHEETS

By Kenneth W. Gatland, F.R.A.S.

A-9 (Project only)—Germany—Army, Peenemünde.

(*a*) Róle: Strategic, long-range, surface-to-surface (with A-10 booster).
(*b*) Origin: 1942 (design).
(*c*) Length: 46·6 ft.
(*d*) Diameter, body (max.): 5·4 ft.
(*e*) Diameter, over fins: Not known.
(*f*) Diameter, over wings: 12·0 ft.
(*g*) Weight, launching: Not known.
(*h*) Weight, propellant: Not known.
(*j*) Weight, payload: 2,150 lb. (Amatol filling, 1,650 lb.).
(*k*) Thrust: 75,700 lb.
(*l*) Velocity (max.): 9,240 ft./sec. (with A-10 booster).
(*m*) Altitude:
(*n*) Range: 2,500 miles (with A-10 booster) in 35 min.
(*p*) Propellant: nitric acid/diesel oil.
(*q*) Feed system: turbo-pump (hydrogen peroxide steam generator, weight H_2O_2: 752 lb.).
(*r*) Control: see A-4 (and Notes below).

Notes: Design development of A-4b with dart-like wings, strengthened construction and re-designed rocket motor, for use in conjunction with A-10 as booster. Terminal guidance obtained by radio-control during supersonic glide from stations situated on wide base-line, from which both range and azimuth are calculated; over target, missile is set into terminal dive (approx. at speed of sound). Overall length A-9/A-10: 85·3 ft.

REFERENCES

(1) "V-2," by Dr. Walter Dornberger. Hurst and Blackett, 1954.
(2) "Development of the Guided-Missile," by K. W. Gatland. Iliffe and Sons, 2nd edition, 1954.

A-10 (Project only)—Germany—Army, Peenemünde.

(*a*) Róle: Strategic, long range, surface-to-surface (booster for A-9).
(*b*) Origin: 1942 (design).
(*c*) Length: 65·6 ft.
(*d*) Diameter, body (max.): 13·6 ft.
(*e*) Diameter, over fins: 29·5 ft.
(*f*) Diameter, over wings: not applicable.
(*g*) Weight, Launching: 188,130 lb.
(*h*) Weight, propellant: 111,484 lb.
(*j*) Weight, payload: (see A/9).
(*k*) Thrust: 448,000 lb. × 50 to 60 sec.
(*l*) Velocity (max.): 3,960 ft./sec. (at separation of A-9).
(*m*) Altitude: 15·2 miles (at separation of A-9).
(*n*) Range: (see A-9).
(*p*) Propellant: nitric acid/diesel oil.
(*q*) Feed system: turbo-pump (hydrogen peroxide steam generator, weight H_2O_2: 3,307 lb.).
(*r*) Control: Gyro-controlled exhaust vanes/four fixed tail fins.

Notes: Vertical take-off from concrete apron with A-9 as second stage; ascent path modified to angle of 45°. Four tail fins heavily braced to support vehicle on the ground; four long guide-members embedded in concrete apron enter stout vertical tubes, one in each fin. Nose-section of booster slotted to receive A-9 which is backed on to internal "thrust ring."

Several alternative designs considered, one with nitrogen pressure feed instead of turbo-pump.

REFERENCES

(1) "V-2" by Dr. Walter Dornberger, Hurst and Blackett, 1954.
(2) "Development of the Guided-Missile," by K. W. Gatland. Iliffe and Sons, 2nd edition, 1954.

DEACON (Rockoon Project)—U.S.A.—State University of Iowa.

(*a*) Róle: Research, Upper atmosphere (cosmic radiation).
(*b*) Origin: 1952.
(*c*) Length: 16·0 ft.
(*d*) Diameter, body (max.): 8·0 in.
(*e*) Diameter, over fins: Not available.
(*f*) Diameter, over wings: Not applicable.
(*g*) Weight, launching: 200 lb.
(*h*) Weight, Propellant: Not available.
(*j*) Weight, launching: 200 lb.
(*h*) Weight, propellant: Not available.
(*j*) Weight, payload: 30 lb.
(*k*) Thrust; 5,700 lb. × 3·5 sec.
(*l*) Velocity (max.): 4,000 ft./sec.
(*m*) Altitude: 60 miles (balloon launched). 20 miles (ground launched).
(*n*) Range: Not applicable.
(*p*) Propellant: solid (standard J.A.T.O. unit).
(*q*) Feed system: not applicable.
(*r*) Control: none: dynamically stable, four fixed tail fins.

NOTES: Launched from 55 ft. plastic "Sky hook" balloon, helium filled, at altitudes of between 10 and 15 miles; balloon rises with rocket at 800 ft./min.

Deacon is suspended in light slight 100 ft. beneath balloon and small box containing timer, barometric pressure switch and firing batteries suspended from tail of rocket—connection with box severed by violence of acceleration.

Ambient temperature at time of firing — 40° C., motor warmed to 70° C. prior to take-off and transparent sheath placed over rocket to maintain warmth during ascent with balloon; rocket body painted matt black to absorb heat. Instrumentation and equipment include Geiger counter or ionization chamber and small F.M. transmitter. Project sponsored by Office of Naval Research and Atomic Energy Commission. Launchings made from U.S. Coast guard Icebreaker *East Wind*, in vicinity of Northern Geomagnetc Pole. Approx. cost of vehicle: Deacon £280 (without instrumentation); balloon £140.

REFERENCE

(1) "The Deacon-Pioneer in Arctic Space," *Aero Digest*, Aug., 1954, p. 26.

A-4b—Germany—Army, Peenemünde.

(*a*) Róle: Surface-to-surface.
(*b*) Origin: 1944.
(*c*) Length: 46·1 ft.
(*d*) Diameter, body (max.): 5·4 ft.
(*e*) Diameter, over fins: Not known.
(*f*) Diameter, over wings: 20·3 ft.
(*g*) Weight, launching: 28,665 lb.
(*h*) Weight, propellant: 19,300 lb.
(*j*) Weight, payload: 2·150 lb. (Amatol filling, 1,650 lb.).
(*k*) Thrust: 60,000 lb. × 60 to 70 sec.
(*l*) Velocity (max.): 5,000 ft./sec.
(*m*) Altitude: 60 miles (at 45° elevation).
(*n*) Range: 370 miles (in 17 min.).
(*p*) Propellant: alcohol/liquid oxygen.
(*q*) Feed system: turbo-pump (hydrogen peroxide steam generator).
(*r*) Control: see A-4 (and Notes below).

NOTES: Development of A-4 with swept-back wings (area 75 sq. ft.) and enlarged aerodynamic control surfaces (tail). Vertical take-off from launching table and trajectory of departure identical with A-4 but range extended by protracted glide.

Two launched during Winter 1944–45; first unsuccessful due to premature cut-off of motor; second successful. Also piloted version (projected 1944) with swept-back wings (area 145 sq. ft.), pressurized cabin and retractable tricycle undercarriage (ref. (3)).

REFERENCES

(1) "A critical review of German long-range rocket development," by W. G. A. Pening, *Journal of the Royal Aeronautical Society*, July, 1946.
(2) "V-2," by Dr. Walter Dornberger. Hurst and Blackett, 1954.
(3) "Development of the Guided Missile," by K. W. Gatland. Iliffe and Sons, Ltd., 2nd edition, 1954.

ABSTRACTS

Edited by J. HUMPHRIES

A List of Abbreviations of titles of journals was included in the 1954 index An addendum to this list is given below.

Chem. Wk.	Chemical Week.
Combat Forces J.	Combat Forces Journal.
Quart. J. Mech. Appl. Math.	Quarterly Journal of Mechanics & Applied Mathematics.
Rev. Path. Gen. Comp.	Revue de Pathologie Generale et Comparée.
Riv. Med. Aero.	Rivista di Medicina Aeronautica.
Z. angew. Phys.	Zeitschrift für Angewandte Physik.

AERODYNAMICS

See also abs. no. 136.

(101) **Space-flight as an aerodynamic problem.** D. Fiecke, K. Deunert, H. Neuber and E.-Fr. Gebauer. *Weltraumfahrt*, **5**, 112-122 (*Oct.*, 1954) (*In German*). Aerodynamic problems of high speed flight with specific reference to wings at high Mach numbers. It is shown that a normal aircraft plan form might be the best shape under these conditions.

ASTRONAUTICS

See also abs. no. 101.

(102) **Red star in space.** M. Caidin. *Astronautics*, **1** (1), 8-9, 33 (*Fall*, 1954). Possibility of a Russian artificial satellite.

(103) **Training for space.** J. G. Vaeth. *Astronautics*, **1** (1), 1-6, 30, 32 (*Fall*, 1954). Discusses methods of training and equipment for future space crews.

(104) **Why conquer space?** F. L. Whipple. *Astronautics*. **1** (1), 7 (*Fall*, 1954). Personal reasons.

(105) **Space flight needs only money, time.** F. C. Durant. *Aviation Wk.*, **61** (13), 46, 48, 52 (*Sept.* 27, 1954). Description of Fifth Congress of International Astronautical Federation and abstracts of some of the papers.

(106) **The crucial problem in astronautics: recovery of multistage vehicles.** G. A. Crocco. *Jet Propulsion*, **24**, 313-5 (*Sept.-Oct.*, 1954). Deals with the problem of high-speed descent through the atmosphere and suggests means of avoiding destructively high temperatures. (5 *refs.*)

(107) **Impression of the 5th International Astronautical Congress.** H. K. Kaiser. *Weltraumfahrt*, **5**, 97-102 (*Oct.*, 1954 (*In German*).

(108) **Compensation for path deviations by continuous rocket thrust.** B. Thüring. *Weltraumfahrt*, **5**, 103-108 (*Oct.*, 1954) (*In German*). Method of compensating the flight path of a spaceship for the perturbations of heavenly bodies, with examples.

(109) **Stationary rocket trajectories.** D. F. Lawden. *Quart. J. Mech. Appl. Math.*, **7**, 488-504 (*Dec.*, 1954). Conditions to be satisfied by a rocket trajectory joining two specified terminals in space, if it is to be stationary relative to fuel expenditure, are calculated. (4 *refs.*)

(110) **New light cast on space flight.** D. A. Anderton. *Aviation Wk.*, **61** (25), 32, 34, 36, 38 (*Dec.* 20, 1954). Abstracts of some of the papers delivered at the 9th A.R.S. Anniversary Convention, Nov. 30-Dec. 2, 1954.

(111) **Reaching for the stars.** G. A. Crocco. *Interavia*, **10** (1), 22-23 (*Jan.*, 1955). General review of space-flight with specific reference to staging and refuelling. (3 *refs.*)

(112) **Walt Disney films space-flight.** W. Ley. *Weltraumfahrt*, **6**, 8-11 (*Jan.*, 1955) (*In German*).

(113) **Research in aircraft flight and space-flight.** E. Sänger. *Weltraumfahrt*, **6**, 12-21 (*Jan.*, 1955) (*In German*). Review of the research required in various branches of physics and chemistry.

ASTRONOMY

See also abs. no. 121.

(114) **The diameters of the satellites of Jupiter, of Titan and of Neptune, measured with a birefringent micrometer of high resolving power.** A. Dollfus. *C.R. Acad. Sci., Paris*, **238**, 1475-1477 (*May* 5, 1954) (*In French*). Io 3,550 km., Europa 3,100, Ganymede 5,600, Callisto, 5,050, Titan 4,950, Neptune about 45,000. (12 *refs.*)

(115) **Report of a symposium of meteor physics at Jodrell Bank**. *Observatory*, **74**, 195-207 (*Oct.*, 1954). Reports of a number of papers including "General problems in meteor physics," "Radio echo investigations: ionization and excitation," "Meteors and the upper atmosphere," "Astronomical problems of meteors" and "Meteors and the International Geophysical Year."

(116) **Research into the water vapour content of the Martian atmosphere.** *C.R. Acad. Sci., Paris*, **239**, 945-946 (*Oct.*, 18, 1954) (*In French*). Spectrographic measurements made from a free balloon at 7,000 m. altitude show that the water vapour in the Martian atmosphere is less than in the Earth's atmosphere at this altitude. (5 *refs.*)

(117) **Interpretation of some Martian features.** D. B. McLaughlin. *Irish Astr. J.*, **3**, 109-111 (*Dec.*, 1954). Deals with theory that the dark areas of Mars are due not to vegetation but to volcanic ash.

BIOLOGY AND MEDICINE

(118) **Condition of subgravity and elimination of the effect deriving from accelerations.** R. Margaria. *Riv. Med. Aero.*, **16**, 469-474 (*Oct.-Dec.*, 1953)(*In Italian*). Suggestion to immerse body in fluid having same specific weight as body in order to simulate free fall. (6 *refs.*)

(119) **Physiological problems raised by astronautics.** P. Gaspa. *Rev. Path. Gen. Comp.*, **53**, 1485-1503 (*Dec.*, 1953) (*In French*).

(120) **Flight above 50,000 feet:—a problem in control of the environment.** J. P. Henry. *Astronautics*, **1** (1), 12-19. (*Fall*, 1954). Limitations of the human body.

(121) **Astrobotany**. V. Kourganoff. *Astronomie*, **68**, 432-436 (*Nov.*, 1954) (*In French*). A summary of the work carried out by Russian workers with regard to spectrographic investigations, with special reference to Mars.

(122) **High-speed man must have brakes.** *Weltraumfahrt*, **6**, 6-7 (*Jan.*, 1955) (*In German*). Pictures and description of the high-speed rocket sled tests undergone by Dr. J. P. Stapp. Deceleration reached was 22 g. for 1/25 sec.

(123) **Space-equivalent conditions within the Earth's atmosphere**. H. Strughold. *Weltraumfahrt*, **6**, 2-5 (*Jan.*, 1955) (*In German*). Shows that all the conditions to be catered for in space (cosmic rays, meteors, oxygen concentration etc.) become effective within the atmosphere (i.e., less than 200 km. altitude). (22 *refs.*)

CHEMISTRY

(124) **Ignition delay with rapidly mixed liquid reactants.** L. Baker. (*Illinois Inst. Tech., Dept. Chem. Tech. Rept. No.* 7, 238 pp. (*Aug.* 7, 1954).

PROJECTILES

(125) **Birds of Mars.** J. N. Leonard. *Antiaircr. J.*, **95** (1), 33-37 (*Jan.-Feb.* 1952). General review of the principles of guided missiles. [Originally published in *Time*, **57** (21), 32-35 (*May* 21, 1951).]

(126) **Guided-missile guidance.** R. W. Fye. *Antiaircr. J.*, **95** (6), 32-35 (*Nov.-Dec.*, 1952). Systems for a fixed target. [Also in *Combat Forces J.* (*July*, 1952).]

(127) **A history of rockets and missiles.** M. L. Kasman. *Antiaircr. J.*, **96** (4), 16-17 (*July-Aug.*, 1953).

(128) **Guided missiles.** H. H. Porter. *Antiaircr. J.*, **96** (6), 5-10 (*Nov.-Dec.*, 1953). Choice of propulsion unit, various guidance systems, method of use and costs. [Originally published in *Aero. Engng. Rev.*, **12** (7), 24-29 (*July*, 1953).]

(129) **Experts describe big studies in missiles.** D. A. Anderton. *Aviation Wk.*, **61** (24), 13-14 (*Dec.* 13, 1954). Résumé of lecture by Maj.-Gen. Leslie A. Simon reviewing recent advances in long-range missiles.

(130) **Swiss guided missile.** *Flight*, **67**, 7-9 (*Jan.* 7, 1955). Full description of the Oerlikon Type 54 anti-aircraft missile and allied equipment. The missile is a beam-rider of 771 lb. all-up weight and is powered by a nitric acid/kerosine rocket motor producing 2,200 lb. thrust.

(131) **How Nike keeps U.S. sky watch.** *Aviation Wk.*, **62** (4), 44 (*Jan.* 24, 1955). Photos of the detailed handling of Nike.

ROCKET MOTORS

(132) **Combustion instability in rocket motors.** L. Crocco. *AGARD Publication AG5/P2*, 32-53 (*Dec.*, 1952) (*In English and French*). Review of existing theories.

(133) **A note on the utilization of radiant energy from the Sun in rockets.** W. M. Conn. *Amer. J. Phys.*, **22**, 341 (*May*, 1954). Proposal to use a working fluid heated by concentrated solar radiation. (5 *refs.*)

(134) **Temperature measurements in rocket exhausts.** F. Rossler. *Z. angew. Phys.*, **6**, 229-231 (*May*, 1954) (*In German*). Use of the sodium line reversal method giving practical figures measured along a rocket flame.

(135) **Vibrational temperature lag during nozzle expansion for the hydrogen fluorine rocket motor.** H. C. Penny and H. Aroeste. *Calif. Inst. Tech., Jet Prop. Cent. Tech. Rept. No.* 5, 4 pp. (*June*, 1954).

(136) **Aerodynamic losses in low-pressure tailpipe exhaust ducts for rocket-propelled aircraft.** W. N. Hagginbottom and J. C. Thibodaux. *NACA Res. Memo. No. L8 C25* (*July* 20, 1948).

(137) **Tiny new rocket engines boost payload for copters.** *Aviation Wk.*, **61** (13), 17 (*Sept.* 27, 1954). Photos of Reaction Motors' hydrogen peroxide motor for fitting to helicopter rotor tips.

(138) **Problem of cooling nuclear working fluid rockets operating at extreme temperature.** H. J. Kaeppeler. *Jet Propulsion*, **24**, 316-9 (*Sept.-Oct.*, 1954). A method for cooling linear heat sources is studied. Examples show that, even at operating temperatures beyond 10,000° K., sufficient cooling efficiency may be expected. (3 *refs.*)

(139) **Enter the super rocket.** K. Stehling. *Aviation Age*, **22** (6), 16-23 (*Dec.*, 1954). Problems of designing rocket motors of 50,000 lb. thrust and above. It is not thought that multiple-chamber layouts will be used because of their higher weight and complexity.

(140) **Bell builds rocket engine knowhow.** D. A. Anderton. *Aviation Wk.*, **62** (2), 28-31 (*Jan.* 10, 1955). Description of Bell's facilities.

(141) **Rocket combustion instability investigated.** *Flight*, **67**, 40 (*Jan.* 14, 1955). Describes experimental work aimed at controlling combustion chamber pressure variations of high frequency by selection of chamber materials. Bronze liners show promise.

(142) **Rocket test house.** *Flight*, **67**, 86 (*Jan.* 21, 1955). New Armstrong Siddeley rocket test house having an explosive limit of 1,500 lb.

ROCKET PROPELLANTS

See also abs. no. 124.

(143) **Flame zone spectroscopy of solid propellants.** R. G. Rekers and D. S. Villars. *Rev. Sci. Instrum.*, **25**, 424-429 (*May*, 1954). Description of equipment with experimental results. (1 *ref.*)

(144) **Probing propellants' future.** *Chem. Wk.*, 64, 66, 68 (*June* 5, 1954). Thiokol Corp's. work on solid propellants.

(145) **Chemical fuels for rockets.** G. Partel. *Alata*, **10** (11), 29-30 (*Nov.*, 1954) (*In Italian*). Special reference to high-energy propellants.

REVIEW

Space, Gravity and the Flying Saucer

(By Leonard G. Cramp. Published by T. Werner Laurie, London. 10s. 6d. net. 178 pp.)

The objects of this book are twofold: to summarize the evidence in favour of the view that our planet is at present being visited by inhabitants of other worlds and to present a theory which the author believes is able to account for the main characteristics which he claims observations of numerous individuals show their flying machines or "saucers" to possess. The author succeeds admirably in achieving his first object. He has no new evidence to offer, but presents the testimony upon which his case is founded in a fair and scientific manner, at the same time shooting a number of shrewd darts at the "closed-mind" type of individual who dismisses any phenomenon not in accord with present scientific theories as *ipso facto* false. However, his attempt to formulate a theory to explain the kinematic behaviour of the flying saucer soon gets out of hand and culminates in a grande finale in which the author, with the composure of a practised conjurer, produces space, radiation, gravitation and matter from a hat which is demonstrably empty save for a mess of "creative rays" of both the modulated and unmodulated varieties. Such a feat may well be the envy of theologians, but, there being as yet no known detectors of creative rays, the doctrine lacks a quantitative basis and for this reason alone it is unlikely to attract scientists as an alternative to other theories whose claims are less startling but whose prognosticative value is greater.

As an indication of the extent to which Mr. Cramp's theory can enlighten us, consider his explanation of our sense of time. This, he states, is our apprehension of the frequency of the creative rays. As these sweep by we subconsciously count the cycles. It follows that if we move in the direction of their propagation, we experience an apparent reduction in their frequency (the Doppler effect) and accordingly time passes more slowly. This is held to explain a well-known phenomenon. The author fails to draw the conclusion that if we reverse our direction of motion, time should pass more quickly. This is contrary to the evidence provided by the observed rates of decay of rapidly moving mesons. These rates depend only upon the speeds and not on the directions of motion.

The characteristic of the flying saucer which initiates this philosophical inquiry is its remarkable manoeuvrability. Observers have claimed that it is capable of intense acceleration within the atmosphere without giving rise to shock waves or, indeed, to sound of any kind. Some scientists have regarded this evidence as proof that the phenomena are of a non-material character. Mr. Cramp prefers to retain the matter with its concomitant inertia and to introduce his G-field. He postulates the existence of beings who are able to generate gravitational fields without the assistance of matter. Each flying saucer depends for its locomotion upon such a generator. Briefly,

it produces a gravitational gradient and then proceeds to fall down it. The absence of a shock wave is explained by the fact that the air in the vicinity of the saucer is also affected by the G-field to a degree which diminishes with distance and consequently falls with it. Apart from the lack of other evidence supporting the thesis that a gravitational field can exist in the absence of matter responsible for it, according to a well known physical law the force which would be exerted on the saucer by the G-field should be balanced exactly by an opposite force acting on the generator of this field. Assuming, therefore, that the saucer and generator do not part company, the resulting motive force would not be considerable. The author may retort that his hypothetical beings repealed Newton's Third Law many years ago when they became aware of its embarrassing consequences. . . .

DEREK LAWDEN.

CORRESPONDENCE

Some Comments and Queries

SIR,

Mr. P. Moore's excellent paper on Mercury in the November, 1954, Journal states that the temperature of the dark side of the planet obtained at Mt. Wilson is only — 70° C. It is true, of course, that radiometric observations of such low temperatures are especially difficult, so that this figure is burdened with considerable uncertainty. Even so there can be little doubt that the night hemisphere of Mercury is substantially warmer than the coldest point of the Moon. This result is difficult to reconcile with what is otherwise known about the innermost Solar planet, yet I think it only goes to show that our present information is somewhat sketchy.

Mr. A. C. Clarke, in his "Astronautical Fallacies," refers to what would happen to an unprotected human body exposed to the vacuum of space, but makes no mention of the intense evaporation of cuticular moisture which must take place and might lead to serious frostbite. I could not say what this effect will amount to numerically, but it seems that the space will feel "very cold."

Finally, Mr. D. F. Lawden's analysis of perturbational manoeuvres contains one aspect of the situation which I find not a little puzzling.

Let us take the example of Mars (p. 333). At Hohmann approach the velocity of the ship relatively to the Sun is 2·65 km./sec. short of the mean orbital velocity of Mars equal to 24·14 km./sec. At the termination of the perturbational manoeuvre the orbital velocity of the ship "relatively to the Sun," or v_1, is increased to 23·82 km./sec. It is therefore, 0·32 km./sec. less than the orbital velocity of Mars, also "relatively to the Sun." If now the pilot has generated this additional velocity of 0·32 km./sec. the ship will fall into the orbit of Mars, apart from a possible difference in the lines of apsides, and their relative velocity will be zero. Yet even without this manoeuvre there should have been a substantial reduction in the relative velocity of the ship and planet, and, in fact, it looks as though this reduction would bring their relative velocity below the point where capture would occur. And yet

we are told that the ship recedes from the planet on the other arm of the hyperbola with the velocity of approach. This would, no doubt, be perfectly correct if the planet were stationary relatively to Sun, but then there would also be no increase in the orbital velocity of the ship round the latter.

Grieff, Perthshire. V. A. FIRSOFF.

(Mr. Moore states: "It is true that our knowledge of the temperature of the dark side of Mercury is very sketchy, but very recent determinations indicate that the Mt. Wilson value is far too high. Mr. Firsoff's criticism was, however, fully justified; as the recent determinations referred to have not yet been published officially, he could not be expected to know about them."

Mr. Lawden replies as follows: "The error in Mr. Firsoff's reasoning consists in his regarding velocity as a scalar rather than as a vector quantity. The velocity of the ship relative to Mars after the perturbation manoeuvre cannot be calculated by a simple subtraction of their speeds. The velocity of Mars must be subtracted *vectorially* from that of the ship and the result will be **u′** (see my Figure 4, p. 333). The magnitude of **u′** is the same as that of **u**, viz. 2·65 km./sec. The perturbation therefore causes no reduction in the magnitude of the relative velocity. If the ship approaches Mars from infinity it will later recede to infinity with the same speed.")

Strughold's Theories of Martian Vegetation

SIR,

I have read with interest Dr. A. E. Slater's comments on Strughold's theories about Martian vegetation (*J.B.I.S.*, Nov., 1954, p. 334) and am inclined to agree with his criticisms. I feel, however, there is one more point not to be ignored, i.e., that the *water* a plant gets from the soil is a constituent of the carbohydrate building materials, and so a source of oxygen that may enter into the photosynthesis-respiration equations when disbursement of oxygen is under consideration.

To my mind, the oxygen contained in the water which a plant takes provides a possibility that a plant can grow in bulk and yet yield a surplus of oxygen. At least there is a better prospect than if it depends solely upon atmospheric carbon dioxide. Personally, however, I have a haunting suspicion that in any case green plants are not the principal agent in maintaining atmospheric oxygen. Indeed, several authorities cite thunderstorms as a factor contributing large quantities of free oxygen.

Incidentally, whilst lecturing in Birmingham two or three seasons ago, I was told that tracer tests have shown that plants disburse oxygen derived from the soil-water, *not from the atmospheric* CO_2. I, for one, would be glad to have authoritative confirmation of this.

Actually, no-one seems to know whether green plants really add more oxygen to the atmosphere, over an extended period, than they subtract and fix. At any rate I have never seen quantitative proof that they *do*. Before we dart off into space with faith, hope and a sixpenny packet of sunflower

seeds in our pocket, I think it would be wise to have indisputable evidence that green plants *are* capable of performing the onerous duty we desire.

This particular aspect of plant metabolism is not only intriguing from an academic standpoint but is of course highly important astronautically, because the propagation of an atmosphere may somewhere, someday, be an urgent problem. In this connection, it occurs to me that one or two of our members may possess the knowledge, time and facilities required to conduct conclusive tests of oxygen disbursement, and thereby perhaps make a valuable contribution to man's extra-terrestrial future. . . . We may even need the answer here on Earth, if our consumption of oxygen continues to increase.

Beaconsfield, Bucks. H. E. Ross.

Some thoughts on a paper by H. E. Ross

SIR,

In a paper entitled "Is Astronautics Escapism" (*J.B.I.S.*, **12**, 175–178), Mr. H. E. Ross criticizes astronauts for being "far more concerned in rebutting technical criticism than in examining and countering criticism and misunderstandings of their practical philosophic aims." It is my opinion that the impossibility of establishing "practical philosophic aims" on the part of astronauts *in toto* makes the concentration on technical matters inevitable.

Mr. Ross suggests that there is a "hope of philosophical and sociological salvation through the colonization of other worlds" if "we are prepared, first, and well in advance of technical adequacy, to make a thoroughly honest and completely objective study of human ends and means." He states that this has never yet been done because those who have attempted it "have had some axe to grind or theologic kink which clouded their minds," but I believe that the difficulty is inherent in Mr. Ross's declared objective. In his own words—"A person can never escape from himself, however far he travels," and although he here refers to physical voyaging, the principle can clearly be applied to philosophic excursions. It is this fundamental limitation that makes it impossible for us to make a thoroughly honest and completely objective study of human ends and means.

Mr. Ross refers to the "battle for the solar system" as "mastering nature." If he is prepared to concede that we manipulate rather than master nature, then the possibility that we shall master ourselves may seem more remote. It is this approach to self that causes many men to seek knowledge of what is right and wrong from God, so that God becomes master and man servant. This attitude of faith in God and his attributes is repugnant to some, but so also, to others, is the attitude that man could be his own master. It is largely a question of faith, and it appears likely that the problem of resolving the different faiths held by man will still be a live issue long after the colonization of new worlds has begun.

In the circumstances, the evolution of the B.I.S. into an essentially technical body appears inevitable.

S. W. GREENWOOD.

Weston-super-Mare, Som.

Some thoughts on a letter by S. W. Greenwood

SIR,

I do not understand Mr. Greenwood's claim that "the impossibility of establishing 'practical philosophic aims' on the part of astronauts *in toto*, makes the concentration on technical matters inevitable." To my mind, the philosophic concepts are just as susceptible to exposition and resolution as are technical aspects.

However, as I understand his attitude, Mr. Greenwood regards astronautical philosophy as of little consequence—perhaps even rather pernicious. I, on the contrary, maintain that the *Why* and *How* of things constitutes a whole which it is dangerous to divide. I do not subscribe to the doctrine that says, "Let's do it anyhow, no matter what." As man's power over nature grows it is increasingly imperative to know what we are doing, for all power has the double edge of good and evil. If space-flight is to be for military purposes, count me out. Granted the B.I.S. must be technical to achieve recognition as an authoritative body, but I cannot acquiesce in the opinion that this is the *sole* or even the principal objective of the organization we have created. Nor am I alone in this view. If the reader will turn to the inside of the back cover of this *Journal* he will find included among the Society's statement of aims the following passage, of which the italics below are mine:—

"... to bring home to the lay public ... *in particular the ultimate implications to human society of the crossing of space.*"

On the point that we can never escape from ourselves, however far we travel, and therefore (says Mr. Greenwood) we can never make a thoroughly honest and completely objective study of human Ends and Means, I beg leave to differ. Aside from the Ultimate Reality of the Universe, and *its* aim, it should be apparent that what *we* can do and what *we* can become matters to *us*. For example, before all else we have to live, and that demands power over nature. It is not a matter of escaping from ourselves, which I agree and have said is impossible, but a case of *knowing* ourselves. I will concur with Mr. Greenwood that we cannot know ourselves completely, but I still assert that for all practical purposes it should be possible to make a thoroughly honest and wholly objective appraisal of human Ends and Means. Not a box for ourselves but simple straightforward generalized directives to guide us. That is, in fact, what Sociology and Psychology are striving to do, without fear or favour. But the findings of these two sciences have not yet been synthesized. Did not Alexis Carrel say "we are the victims of the backwardness of the sciences of life over those of matter?" In any case, the difficulty lies not so much with the determination and agreement of Ends as with the determination and agreement of Means. Hence the Iron Curtain.

I see that Mr. Greenwood dislikes my use of the expression "mastering nature," preferring the word "manipulate." Well, to manipulate is to manage —but surely we are already doing more than that with nature? We are, for instance, making many compounds that do not occur in nature, so far as we know. More—atomic transmutation on a significant scale is being carried out. In all, we cannot remain blind to the fact that many of the erstwhile fantasies

of science fiction are being realized. We *are* beginning to master nature, to crack the whip and make it jump. One day we may even have spaceships.

To continue, when I speak of "mastering ourselves" I do not mean "manipulating ourselves" or changing our intrinsic nature from *Homo sapiens* into *Homo superior* but of creating and using a philosophy which will enable man, *as he is*, to fulfil all his meritorious capacities as an individual and as a species. Incidentally, that is Human Aim Number One, as I see it. I will however agree with Mr. Greenwood that such a prospect lies some way in the future, though perhaps not so far as some pessimists suppose. The point here is not whether we *can* master ourselves but whether we are prepared to make the attempt. Even the various religions, woolly-minded though they are, insist upon this. Certainly, lack of a properly integrated philosophic orientation is the cause of man's present troubles.

In conclusion, I find myself in complete agreement with Mr. Greenwood's remark that God is a matter for individual belief. As Francis Bacon said, "man prefers to believe what he prefers to be true." The trouble comes when the Unknown is used as a basis for human values and action.

The Big Stick is an excellent psychological device, but a relatively primitive one. We must "be good" not because of God but because of *man*.

H. E. Ross.

Beaconsfield, Bucks.

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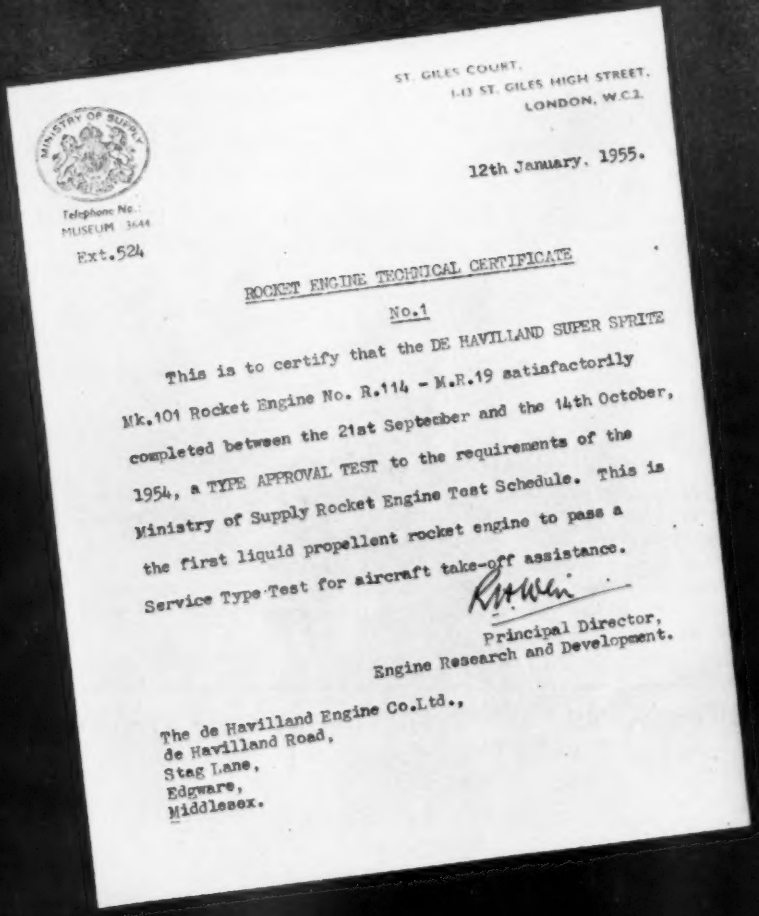

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